SEARCHING FOR THE HIGGS BOSON

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- Collider searches for the Higgs
- – Is it the SM Higgs boson?
- – SUSY & other BSM Higgs sectors

Some recommended references

The Anatomy of electro-weak symmetry breaking. I/II: [SM & MSSM]
Abdelhak Djouadi, hep-ph/0503172 and 0503173.

QCD effects in Higgs physics, [Higgs formulae]
Michael Spira, Fortsch.Phys.46:203-284,1998, hep-ph/9705337.

Higgs statistics for pedestrians, [what happened at LEP]
Eilam Gross & Amit Klier, hep-ex/0211058.

CMS TDR (Technical Design Report), Higgs chapter,
Due out June 20, 2006.

Higgs boson searches at hadron colliders,
Volker Buscher & Karl Jakobs, Int.J.Mod.Phys.A20:2523-2602,2005, hep-ph/0504099.

Prospects for the search for a standard model Higgs boson in ATLAS using vector boson fusion,
S. Asai et al., Eur.Phys.J.C32S2:19-54,2004, hep-ph/0402254.

SM Higgs Reminder (Sally Dawson's lectures)

The SM Higgs sector is the simplest, most economical weakly-coupled explanation for EWSB and fermion mass generation.

- unitarizes $VV \rightarrow VV$ scattering,
- unitarizes $f\bar{f} \rightarrow VV$ scattering
- gives masses to W, Z, and fermions in a gauge-invariant, renormalizeable way

But it does come with some caveats:

- ignores the flavor problem
- no explanation of neutrino masses
- radiative stability problem

That said, SM Higgs is a suitable starting point for *phenomenology*:

$\longrightarrow$ the study of physical phenomena associated with a theory

$\longrightarrow$ the connection between theory and experiment

Purpose of these lectures:

1. show how to look for a Higgs candidate at colliders
2. show how to study a Higgs candidate - confirm a theory
3. explain some Higgs sectors beyond the SM

The SM Higgs $SU(2)_L$ doublet has several parameters:

- 1 “gauge” parameter, v, measured via M_W, G_F, etc.
- 9 Yukawa couplings (fermion mass parameters; ignore ν’s)
- 1 free parameter, M_H

To study these parmeters, must produce Higgs bosons at colliders:

LEP, Tevatron, LHC, SLHC, ILC, CLIC, VLHC, ...

LEP already ran

Tevatron is running

LHC will run in ~ 1 year

what comes next depends on what we find

So how is the SM Higgs boson produced in collision?

$\longrightarrow$ recall the Higgs couples to SM particles $\propto m$

LEP HIGGS SEARCHES

(a brief history)

$M_H \gtrsim 3$ GeV from hadron decays before LEP (ca. 1990)

What about $e^+e^- \to H$ direct production?

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HA! Would take about 4 years to see 1 event at LEP-II

(m_e is just far too small to couple usefully)

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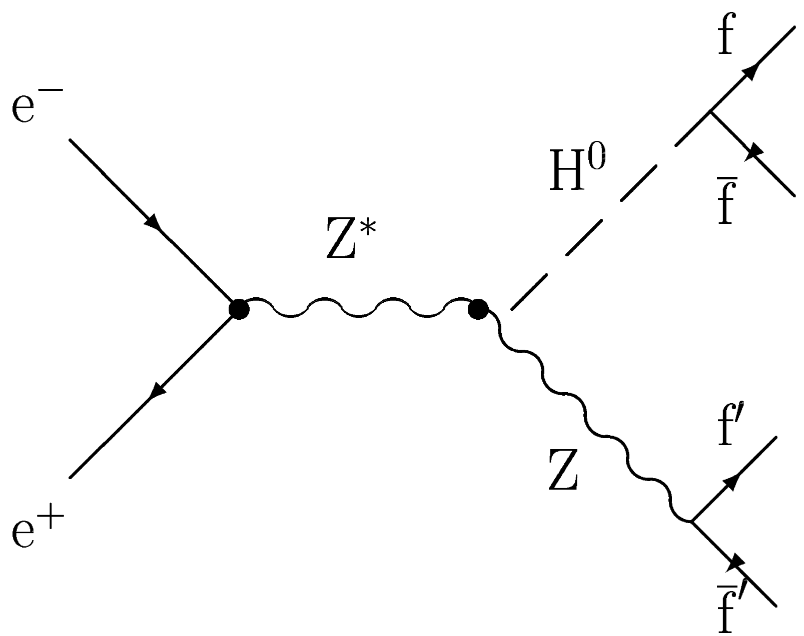
(m_e is just far too small to couple usefully)

How it's really produced: mostly $e^+e^- \to Z^* \to ZH$

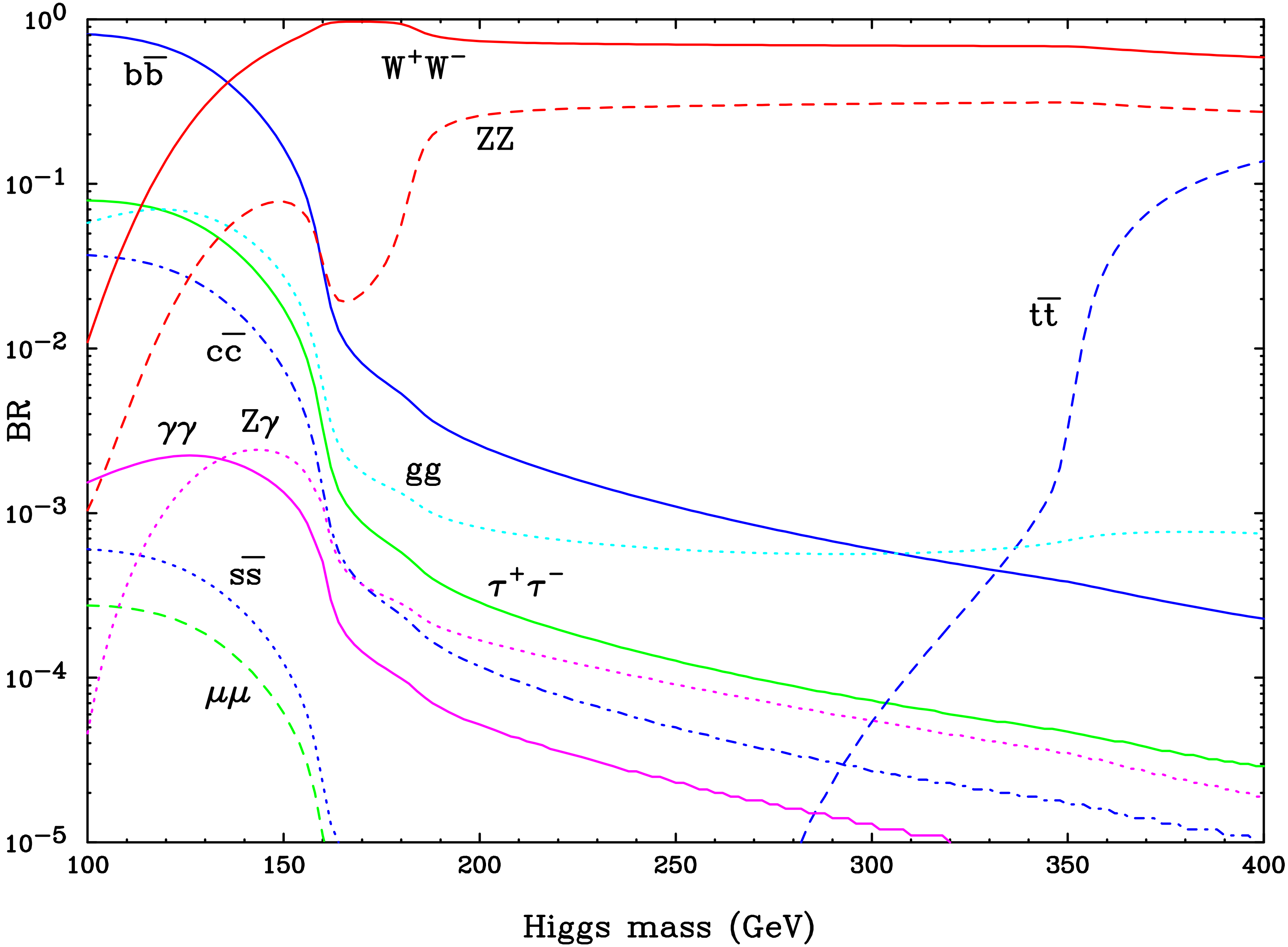


(assume here $M_H \lesssim 150$ GeV or so, so $H \to f\bar{f}$ dominates)

▷ at an e^+e^- collider, can use nearly all Z decays

▶ but then how does the Higgs decay?

H preferentially decays to the heaviest SM pair kinematically allowed



► at low M_H, this is mostly $b\bar{b}$ and $\tau^+\tau^-$

A bit on Higgs partial widths...

1. decays to fermions:

$$\boxed{\Gamma_{f\bar{f}} = \frac{N_c G_F m_f^2 M_H}{4\sqrt{2}\pi}\beta^3} \quad \text{w/} \quad \beta = \sqrt{1 - \frac{4m_f^2}{M_H^2}}$$

· use $m_f(M_H)$ for quarks

· QCD corrections for $\Gamma_{q\bar{q}}$ significant

$\longrightarrow$ notice: *linear* in M_H

$\longrightarrow$ one factor β from matrix element, two factors from phase space

2. decays to gauge bosons

$$\boxed{\Gamma_{VV} = \frac{G_F M_H^3}{8\sqrt{2}\pi}\,\delta_V \beta\left(1 - x_W + \frac{3}{4}x_W^2\right)} \quad \text{w/} \quad \begin{cases} \delta_{W,Z} = 2, 1 \\ \beta = \sqrt{1 - x_W} \\ x_W = \frac{4M_W^2}{M_H^2} \end{cases}$$

$\longrightarrow$ notice: *cubic* in M_H

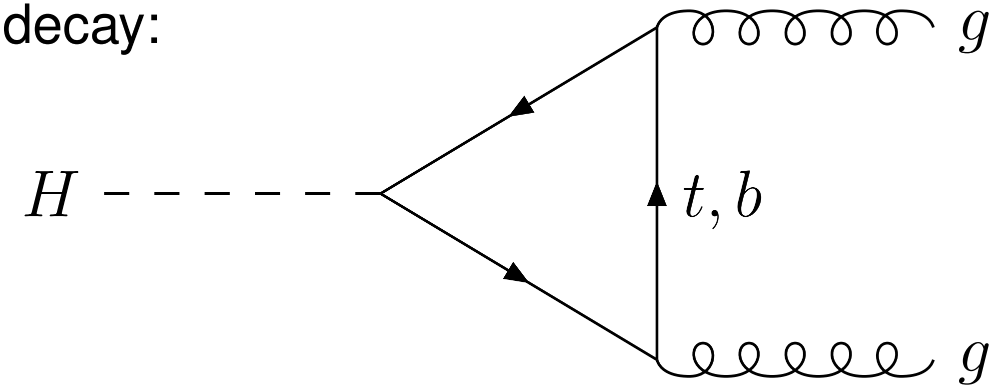
$\longrightarrow$ one factor β from phase space, other part from matrix element

► partial widths to fermions & bosons very different; bosons “win”

A bit on Higgs partial widths...

3. decays to gluons: but gluons are massless!

Loop-induced decay:



$$\boxed{\Gamma_{gg} \;=\; \frac{\alpha_s^2 G_F M_H^3}{16\sqrt{2}\pi^3}\left|\sum_i \tau_i\left[1+(1-\tau_i)f(\tau_i)\right]\right|^2}$$

w/ $\tau_i = \frac{4m_f^2}{M_H^2}$ and $f(\tau) = \begin{cases}\left[\sin^{-1}\sqrt{1/\tau}\right]^2 & \tau \geq 1\\ -\frac{1}{4}\left[\ln\frac{1+\sqrt{1-\tau}}{1-\sqrt{1-\tau}} - i\pi\right]^2 & \tau < 1\end{cases}$

· use $m_f(M_H)$ for quarks; t completely dominates

· QCD corrections significant

· *cubic* in M_H

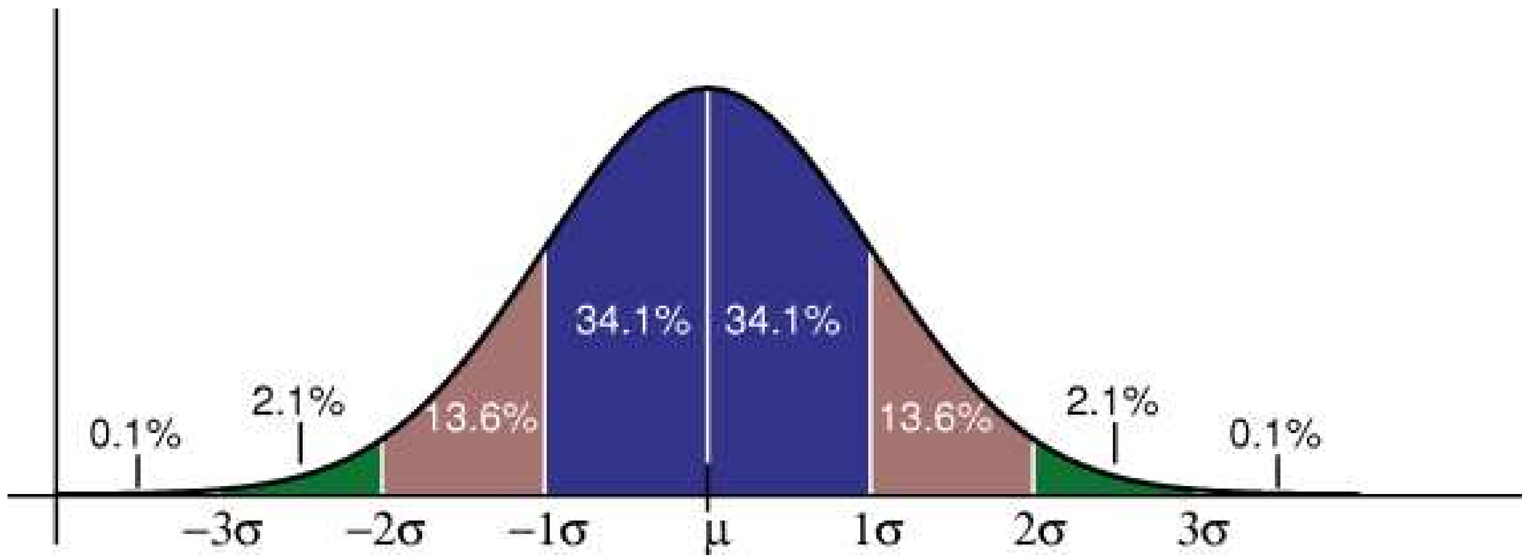
· similar form for $H \longrightarrow \gamma\gamma$, but W loop included

A brief word on statistics...

In any experiment, event counts are quantum rolls of the dice - they follow a Gaussian distribution about the true mean.

$$f(x;\mu,\sigma) \;=\; \frac{1}{\sigma\sqrt{2\pi}}\,exp\left(-\frac{(x-\mu)^2}{2\sigma^2}\right)$$

The statistical uncertainty in the rate then goes as $\sqrt{N}$, the # of events. This is "1 sigma" of uncertainty: 68.2% of the experiments we conduct will obtain N within $\sigma \approx \pm\sqrt{N}$ about $\mu = N_{\rm true}$.



To discover a signal above some known background, we require 5σ: a 0.00006% chance that the signal is only a statistical fluctuation.

LEP-II searched in multiple channels:

$$b\bar{b}jj,\ b\bar{b}\ell^+\ell^-,\ b\bar{b}\nu\bar{\nu},\ \tau^+\tau^-jj,\ jjjj, \ldots$$

Z branching ratios:

$\rightarrow\ \ell^+\ell^-$ 3.3% (each of e,μ,τ)

$\rightarrow\ b\bar{b}$ 15%

$\rightarrow\ \nu\bar{\nu}$ 20% (invisible)

$\rightarrow\ jj$ 55% (everything else)

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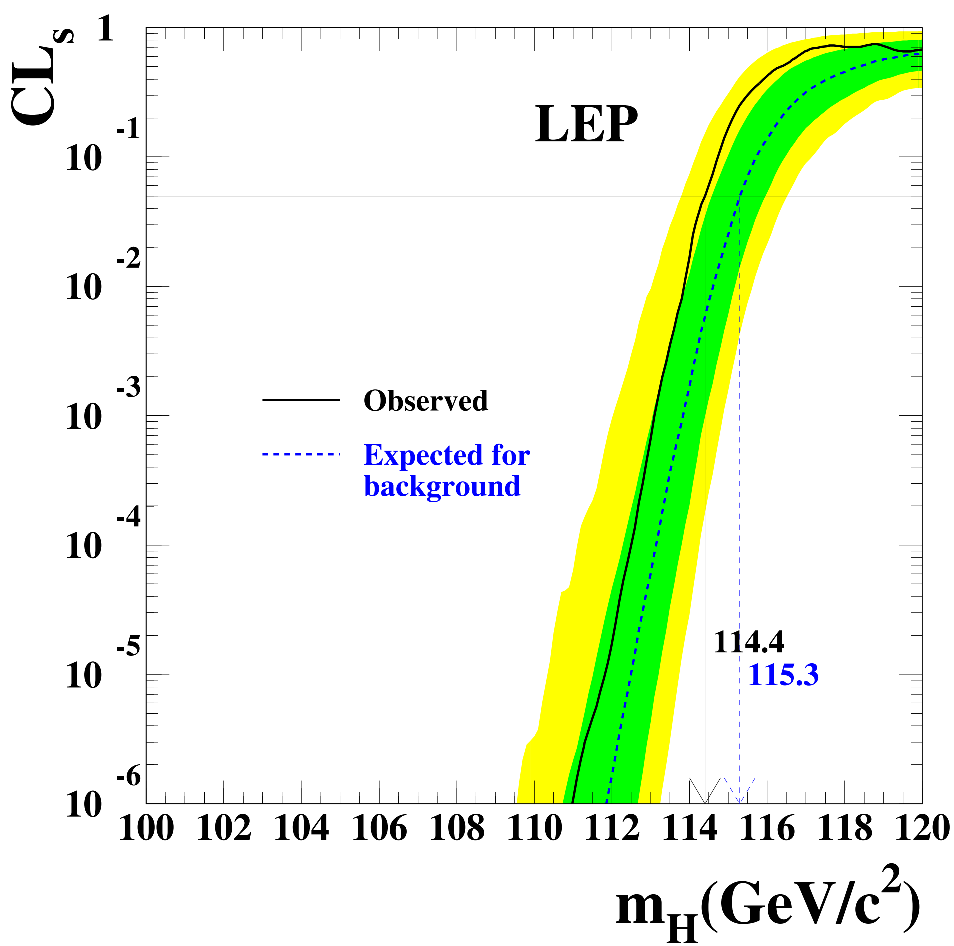
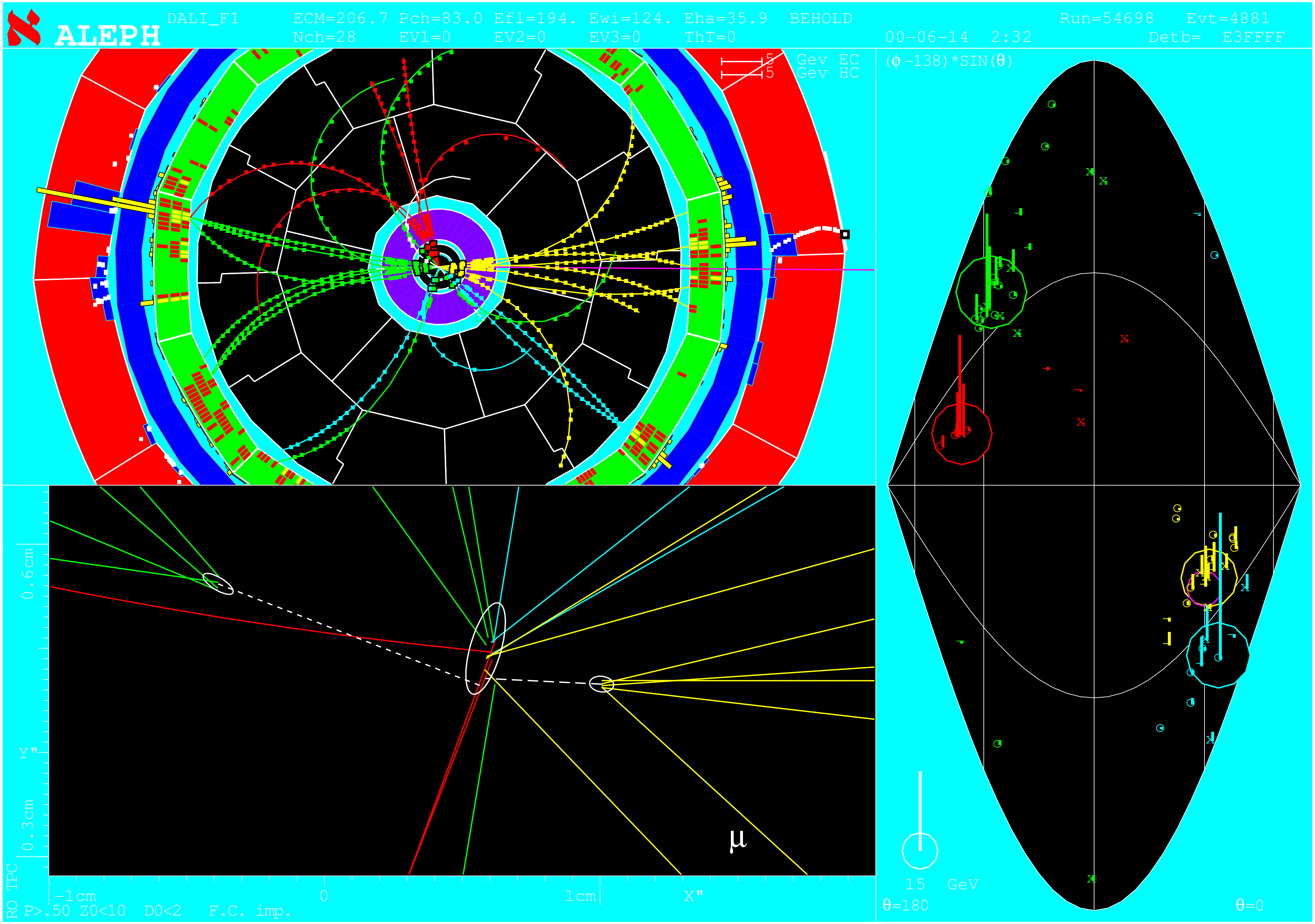
And saw nothing up to the machine kinematic limit ...

...using a 2σ statistical limit.



Or did it? Interesting ℵ event: $Z \to q\bar{q}, h \to b\bar{b}$



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Do *you* play the “1 event” game?

TEVATRON HIGGS SEARCHES

(ongoing)

Higgs searches are much tougher at a hadron collider!

Reason: signal is EW (small), but backgrounds are QCD (large).

A heavy top quark turns out to be a real pain...

“Today’s edge-of-your-seat search is tomorrow’s exciting discovery is next week’s annoying background.”

$p\bar{p}$ collisions are different from e^+e^-, so ask again:

► how do we produce the Higgs at a hadron collider?

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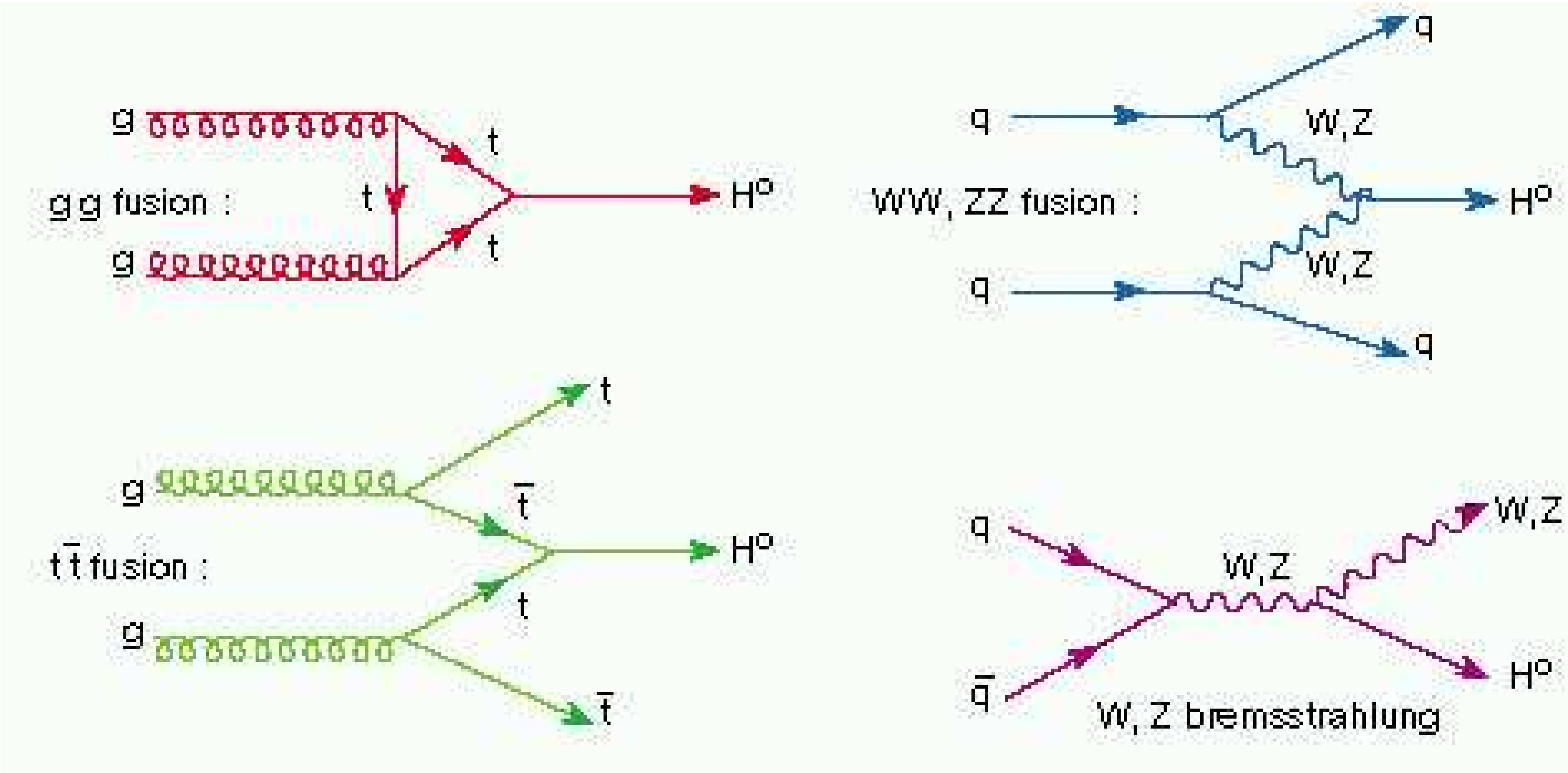
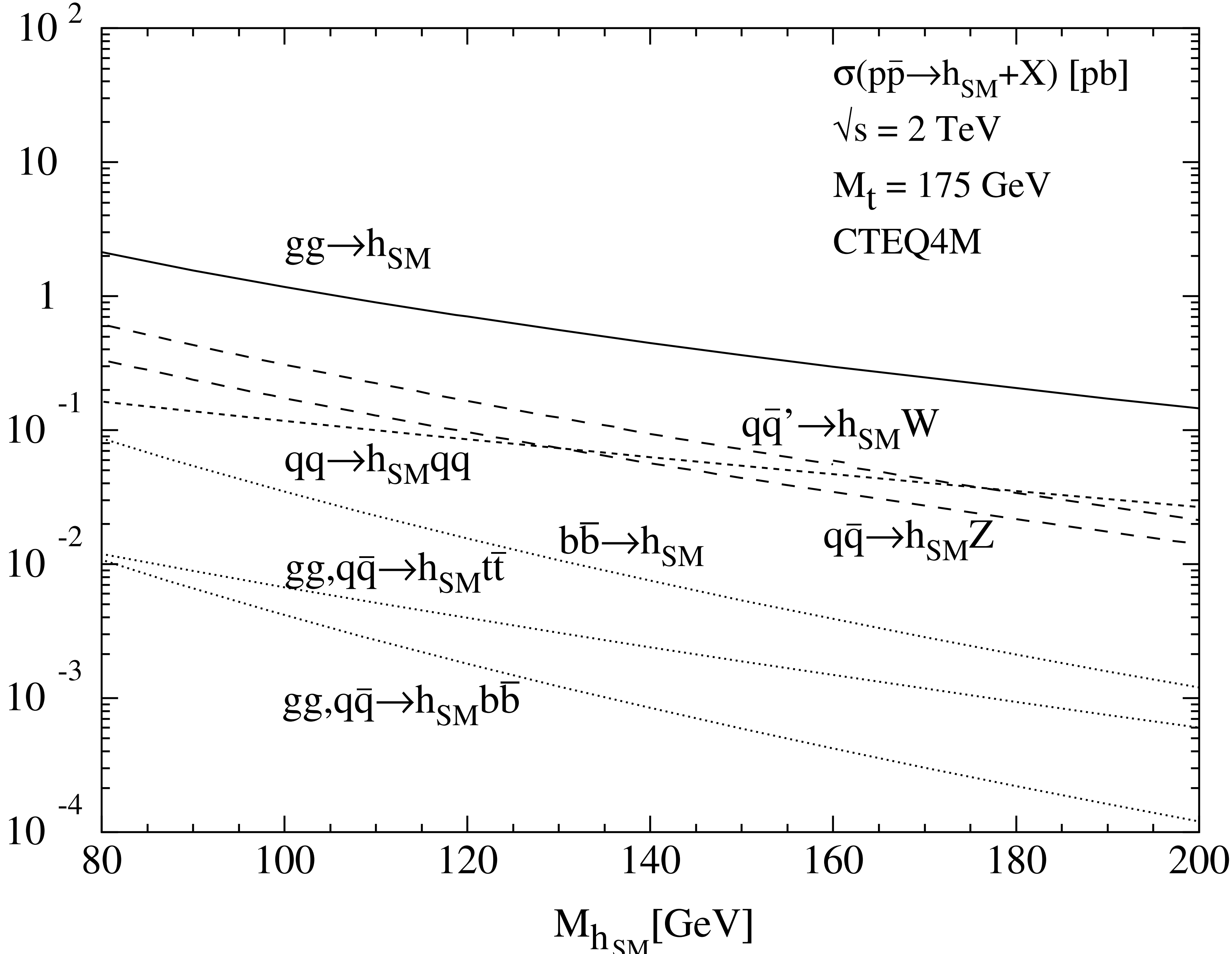
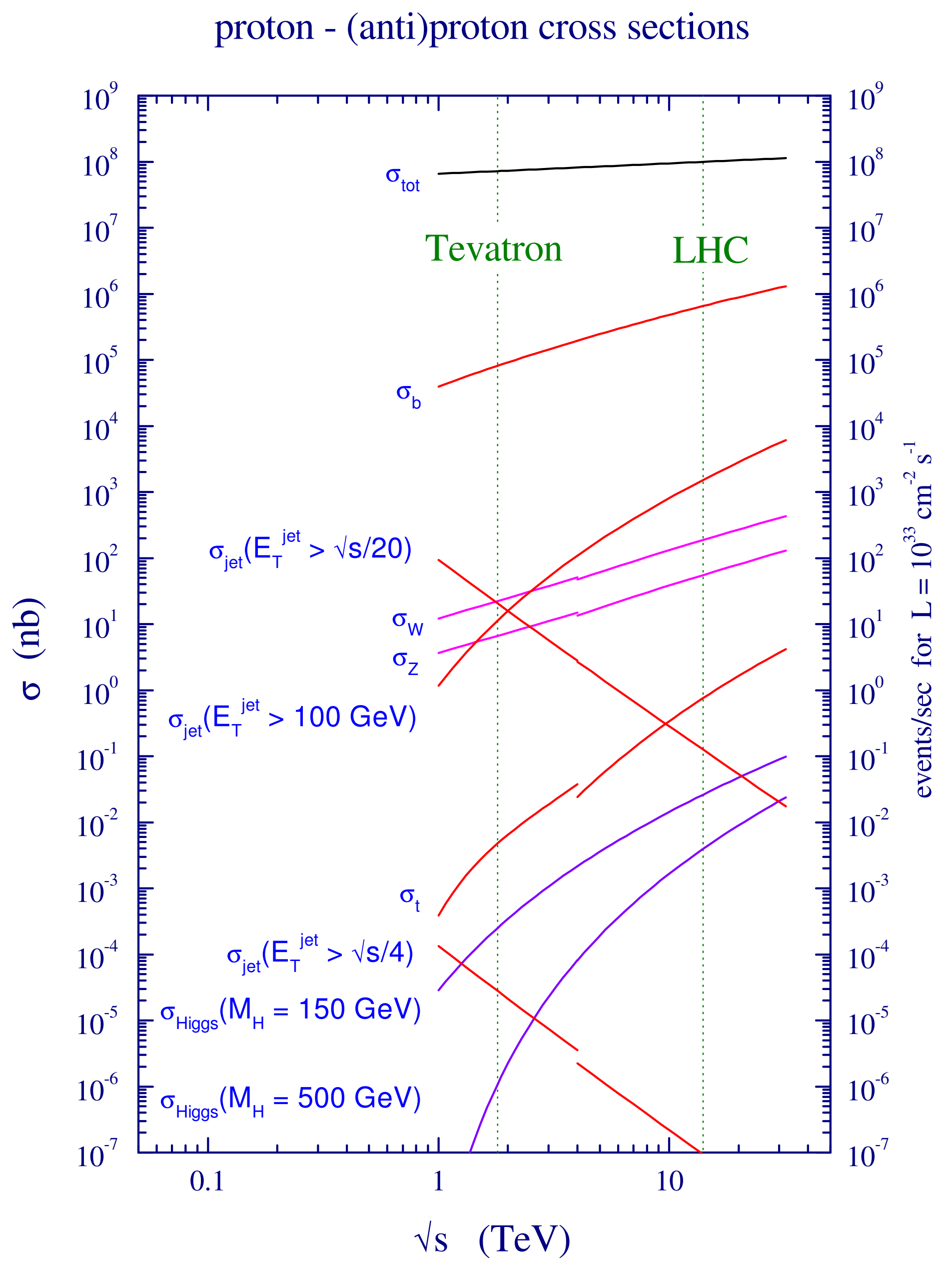


Which process is largest? The answer might surprise...



Ok, $gg \longrightarrow H$ is largest...for a light Higgs, can we do $H \longrightarrow b\bar{b}$?



What channel works best at a hadron collider isn't so obvious...

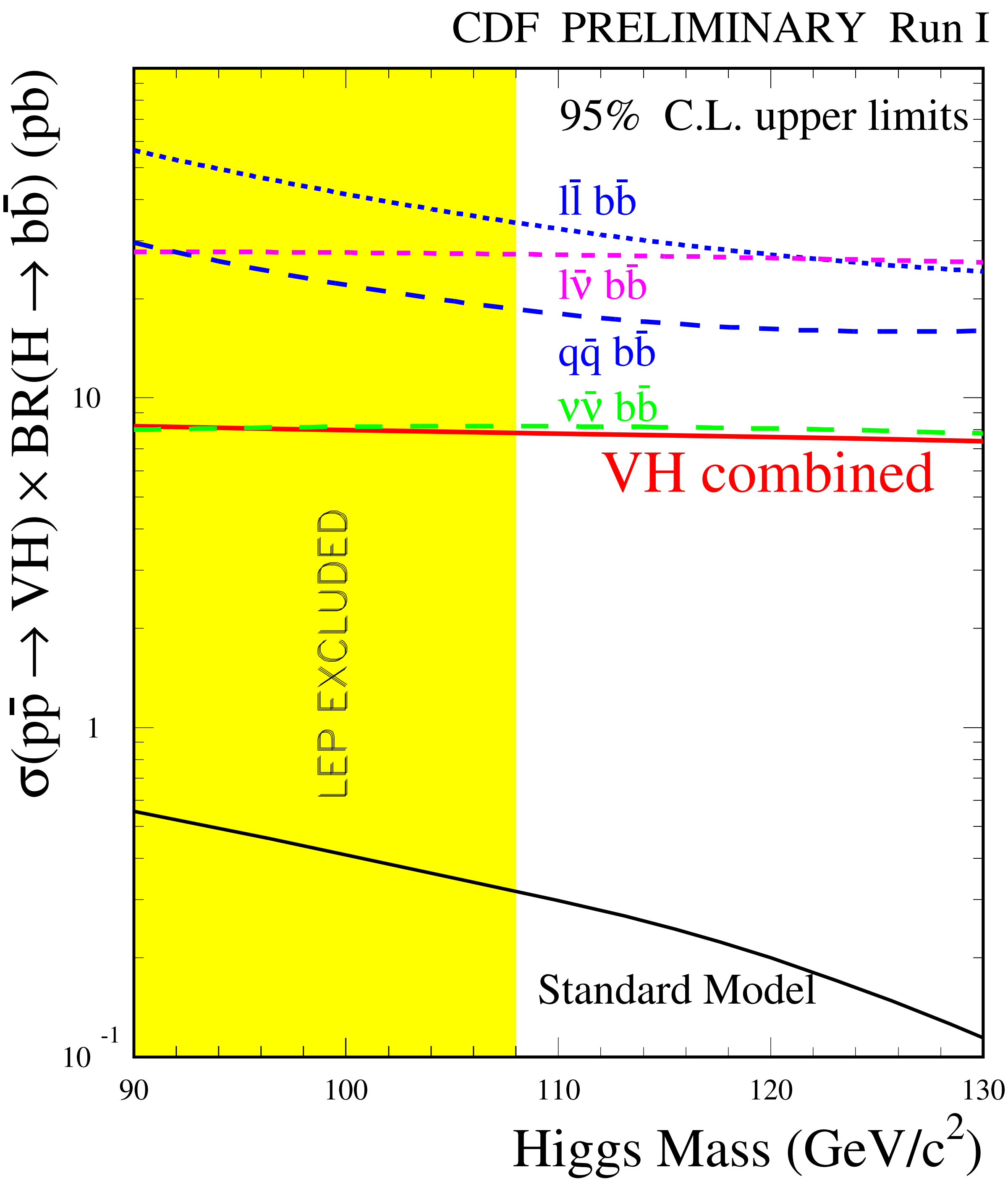
Tevatron uses multiple channels:

- if $H \longrightarrow b\bar{b}$ dominant, then
  - $W^{\pm}H \rightarrow \ell^{\pm}\nu b\bar{b}$
  - $ZH \rightarrow \ell^{+}\ell^{-}b\bar{b}$
  - $WH, ZH \rightarrow jjb\bar{b}$
  - $ZH \rightarrow \nu\bar{\nu}b\bar{b}$

- if $H \longrightarrow W^{+}W^{-}$ dominant, then
  - $gg \rightarrow H \rightarrow W^{+}W^{-}$ (dileptons)
  - $W^{\pm}H \rightarrow W^{\pm}W^{+}W^{-}$ (2ℓ,3ℓ)

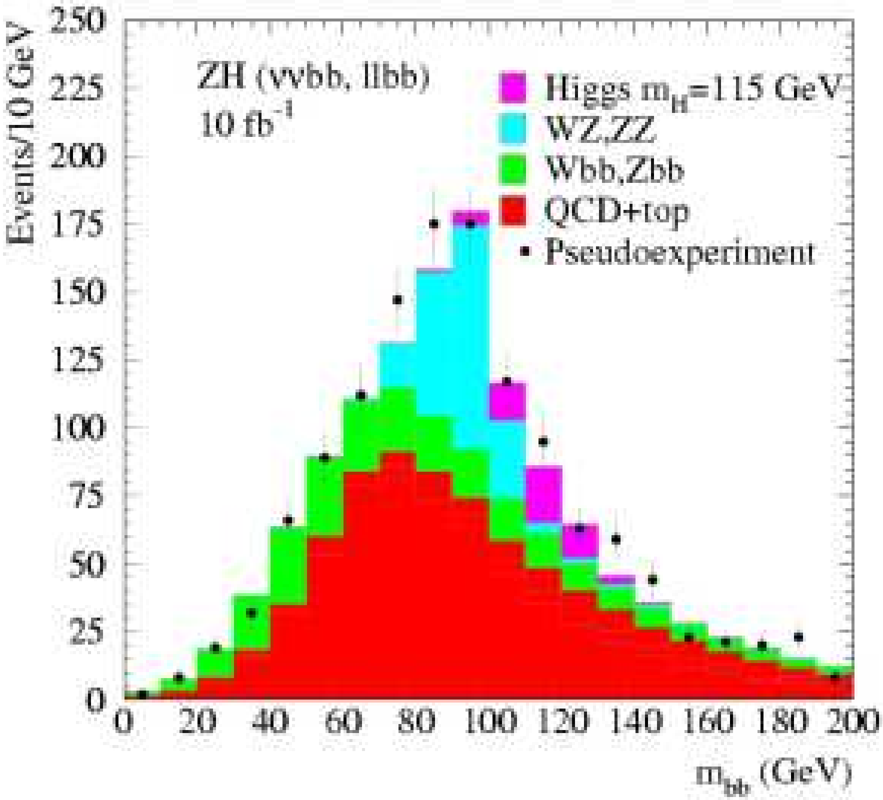
Important point: requiring leptons in the final state gets rid of many QCD backgrounds, but not top quark pairs!

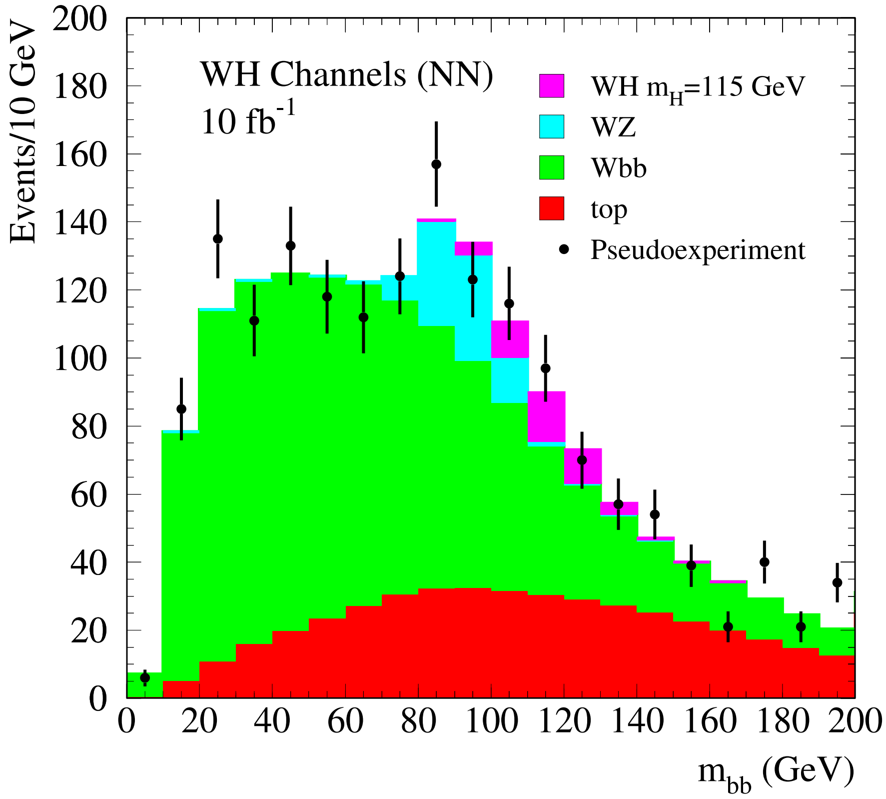
Note that finite jet pair mass resolution $\pm 15 - 20$ GeV seriously complicates a search for a narrow resonance.



$\longrightarrow$ Run I very far from discovery level, but Run II is far superior

For “light” H, $ZH \to \nu\bar{\nu}b\bar{b}$ and $WH \to \ell\nu b\bar{b}$ are the cleanest:

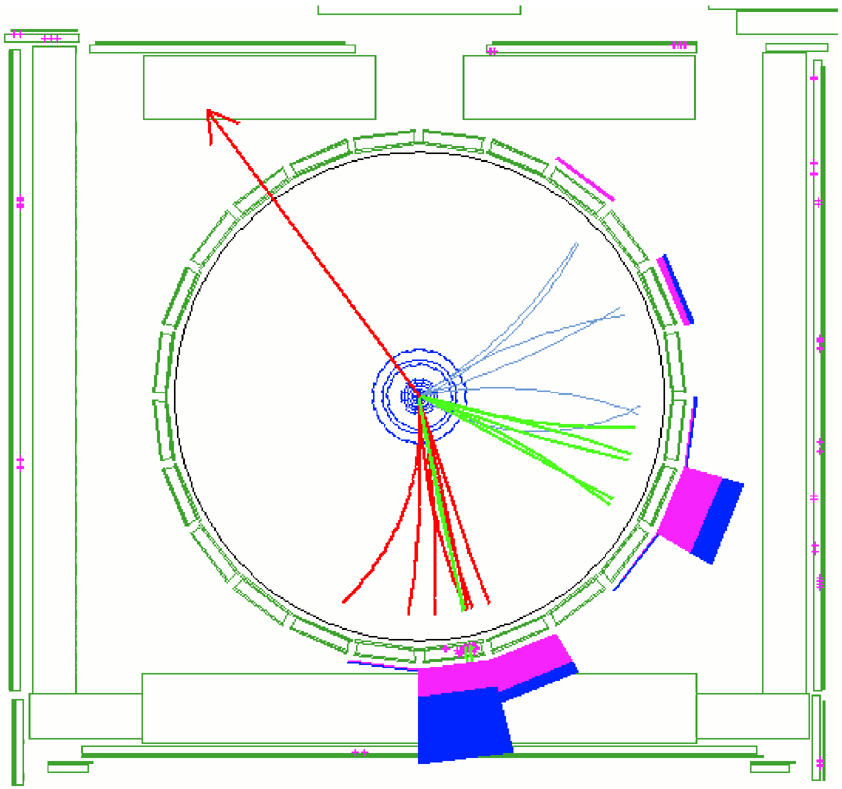


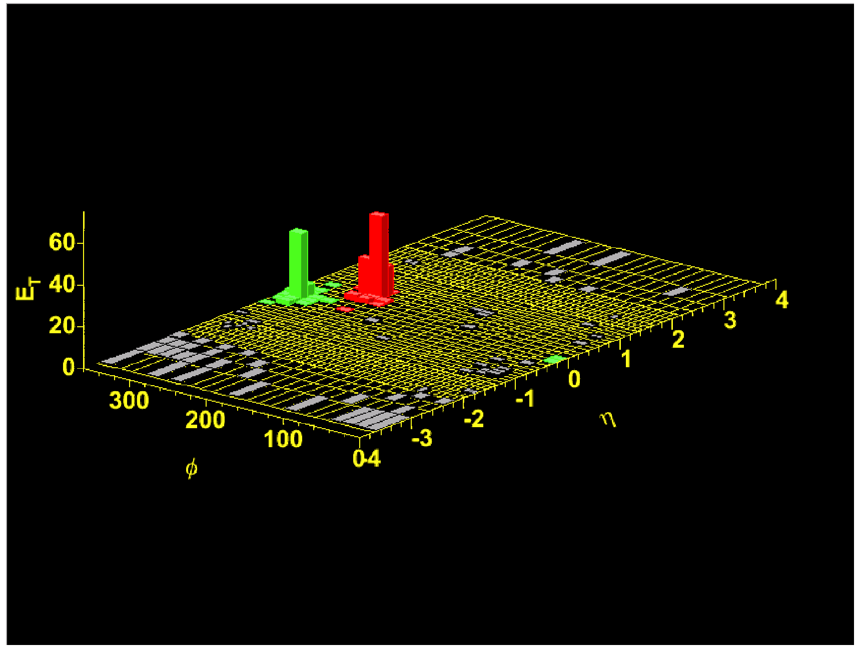


Higgs signal is a very tiny addition to a steeply falling bkg –

how well do we know the bkg shape? (Hint: it’s QCD...)

Example: CDF Run II $ZH \rightarrow \nu\bar{\nu}b\bar{b}$ candidate event





Two b-tagged jets

m_{jj}= 82 GeV

Missing E_T=145 GeV

Jet_1 E_T= 100.3 GeV
Jet_2 E_T= 54.7 GeV

Could be ZZ

$\longrightarrow$ not so straightforward to say what any given event is

For "heavier" Higgs, $gg \to H \to W^+W^-$ is best chance:

- both W's decay to $\ell\nu$ to get rid of QCD bkg

$p\bar{p} \to W^+W^-$ bkg is largest, about 100x SM Higgs signal

Use Dittmar-Dreiner angular lepton correlation to reduce bkg:

$W_T^+W_T^-$ component:

$$W_T^+ \to \ell^+\nu_\ell \propto (1+\cos\theta_\ell)^2$$

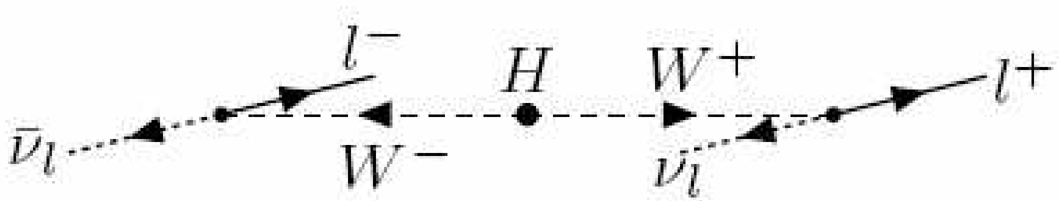
$$W_T^- \to \ell^-\bar{\nu}_\ell \propto (1-\cos\theta_\ell)^2$$

$W^\pm$ spins anti-correlated $\therefore$ emitted in same direction

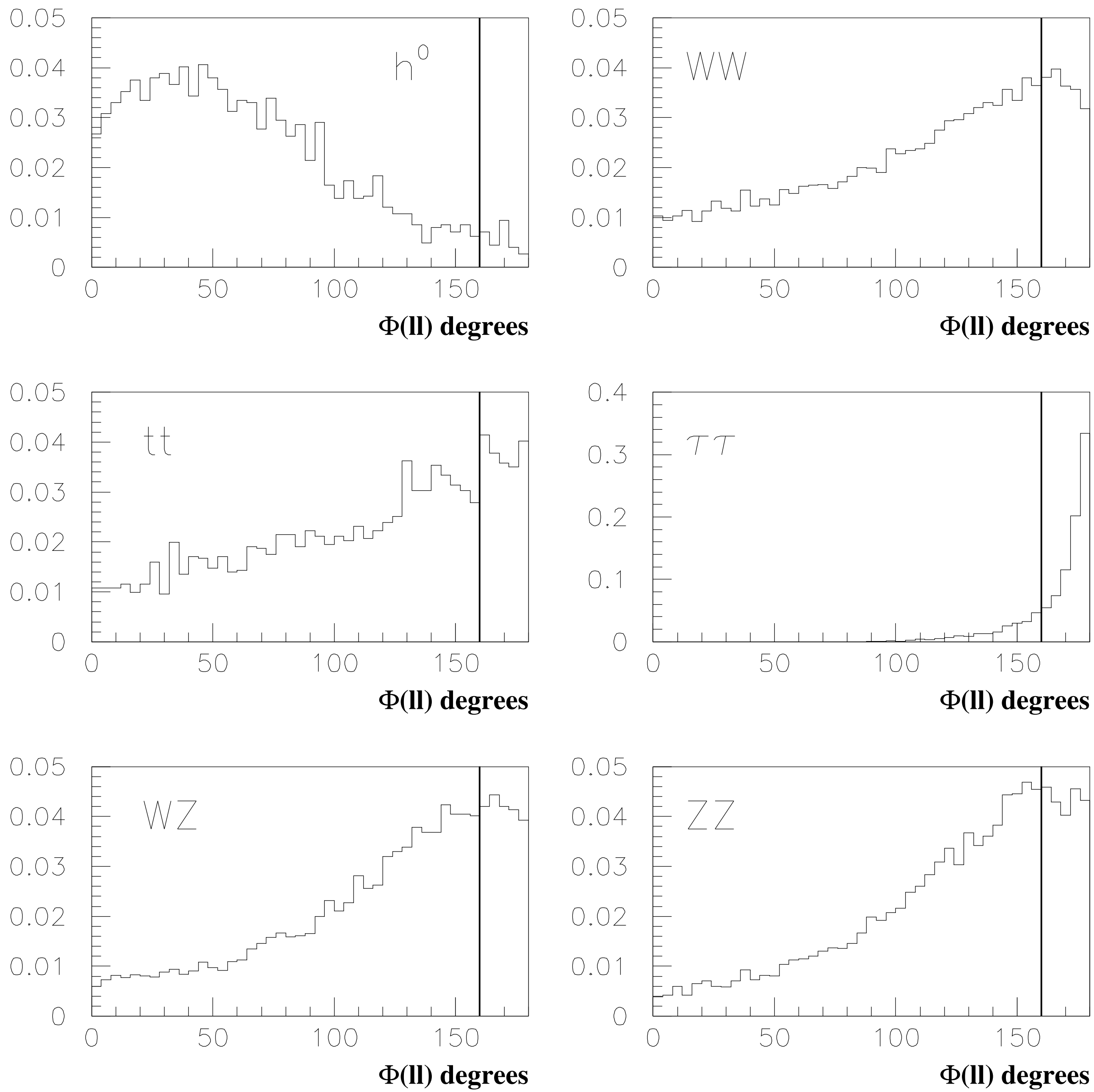
$W_L^+W_L^-$ component:

$|M|^2 \propto (\ell^- \cdot \nu)(\ell^+ \cdot \bar{\nu})$ $\longrightarrow$ same result

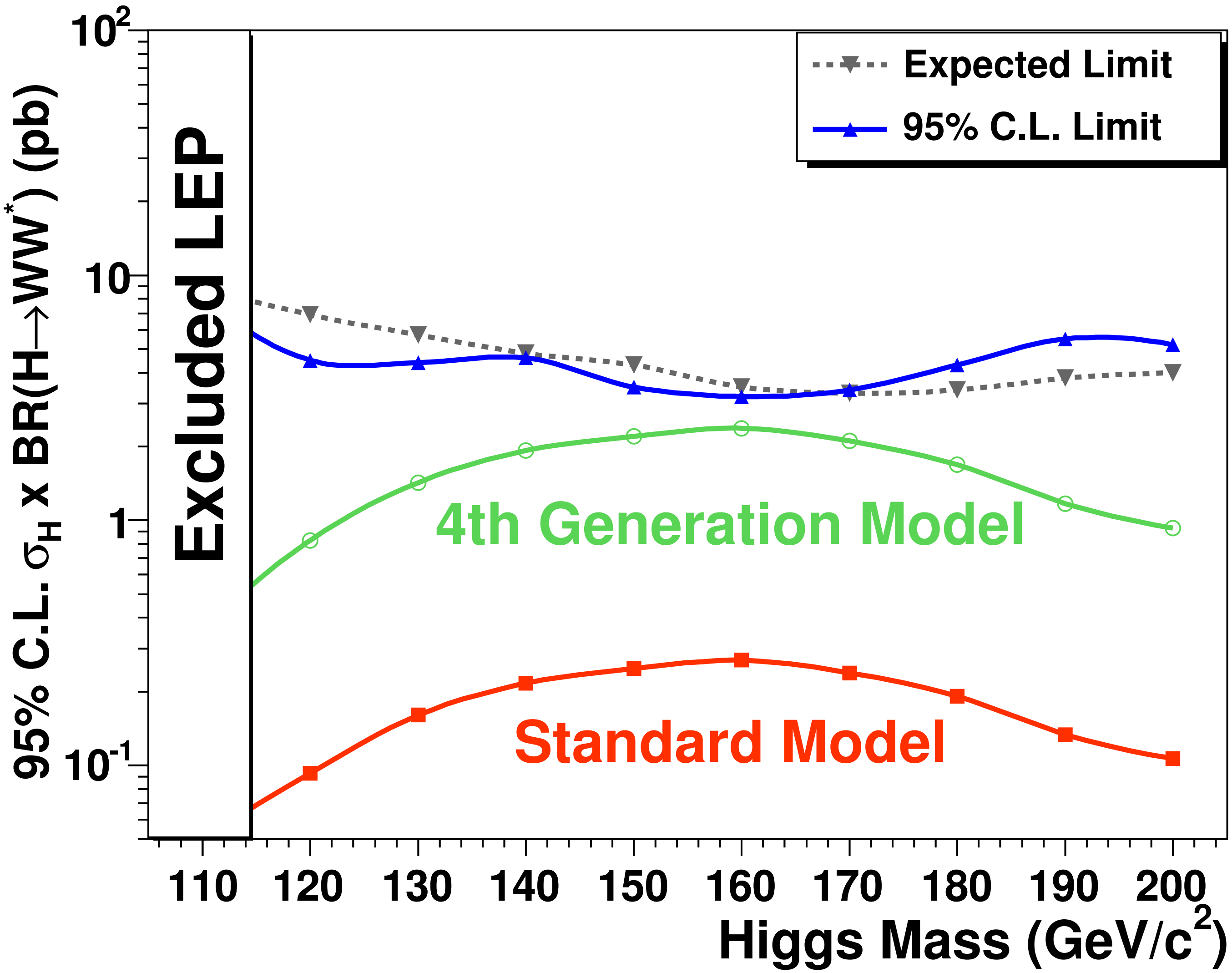
▶ $\ell^+\ell^-$ emitted preferentially together



Tev2 $gg \to H \to W^+W^- \to \ell^+\ell^-\not{p}_T$ lepton angular correlation:



Tev2 $gg \to H \to W^+W^- \to \ell^+\ell^-\not{p}_T$ limits:



$\longrightarrow$ a long way to go, but could rule out some BSM physics soon

Summary of Tevatron Higgs study predictions per 1 fb^{-1}:

(uses advanced neural net (NN)-improved analyses)

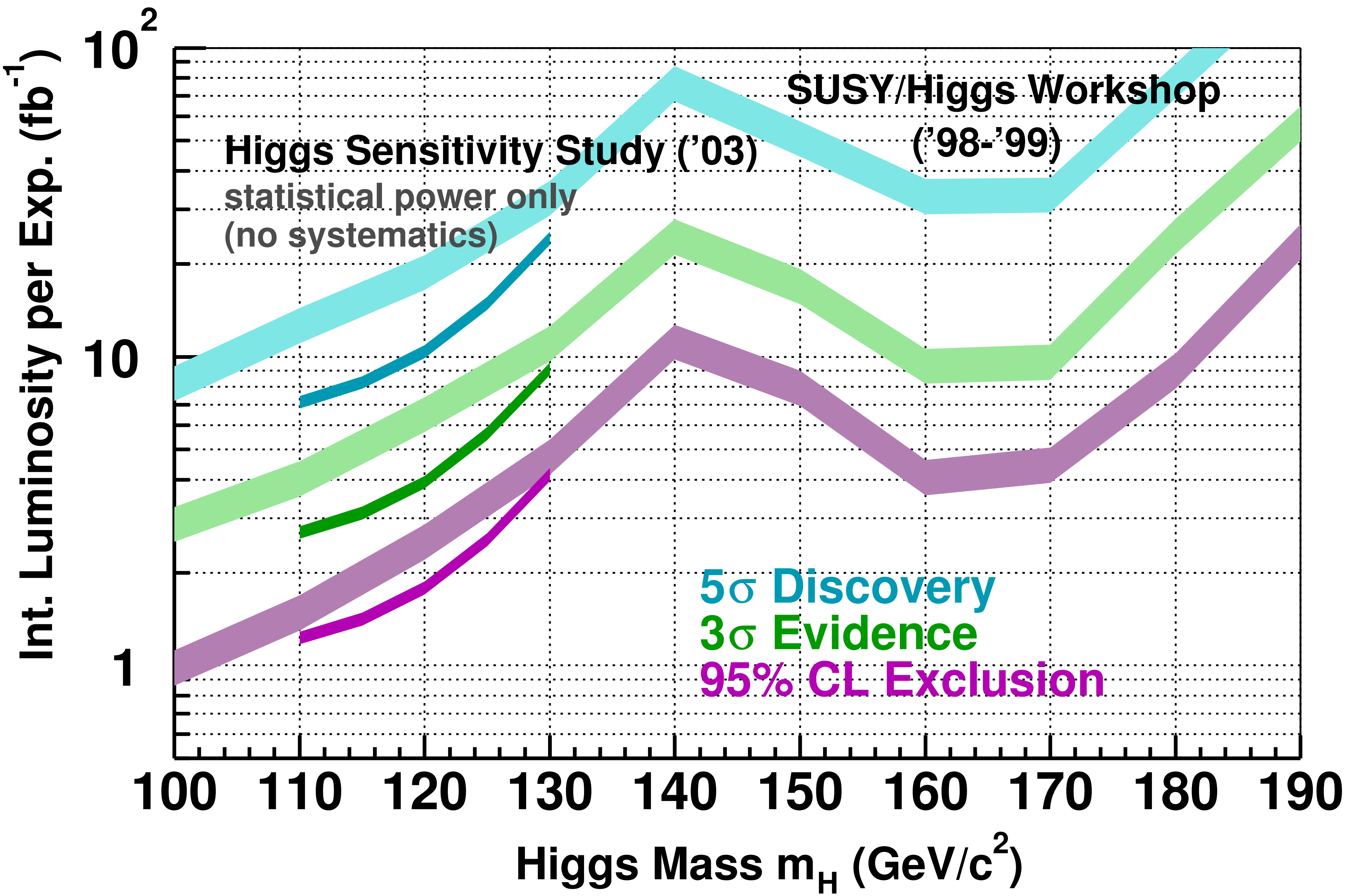
Channel	Rate	Higgs Mass (GeV/c^2) 90	100	110	120	130
$\ell\nu b\bar{b}$ (NN)	S	8.7	9.0	4.8	4.4	3.7
	B	28	39	19	26	46
	$S/\sqrt{B}$	1.6	1.4	1.1	0.9	0.5
$\nu\bar{\nu}b\bar{b}$ (NN)	S	12	8	6.3	4.7	3.9
	B	123	70	55	45	47
	$S/\sqrt{B}$	1.1	1.0	0.8	0.7	0.6
$\ell^+\ell^- b\bar{b}$ (NN)	S	1.2	0.9	0.8	0.8	0.6
	B	2.9	1.9	2.3	2.8	1.9
	$S/\sqrt{B}$	0.7	0.7	0.5	0.5	0.4
$q\bar{q}b\bar{b}$ (SHW)	S	8.1	5.6	3.5	2.5	1.3
	B	6800	3600	2800	2300	2000
	$S/\sqrt{B}$	0.10	0.09	0.07	0.05	0.03

Contemplate: 5 fb^{-1} for $M_H = 120$ GeV in the best channel would be

$S = 23,\ B = 225,\ S/\sqrt{B} = 1.6\sigma$

► Tev2 Higgs search must combine several extremely weak channels

Tevatron Run II search ultimately depends on statistical combination of multiple very weak channels: damned by low luminosity!

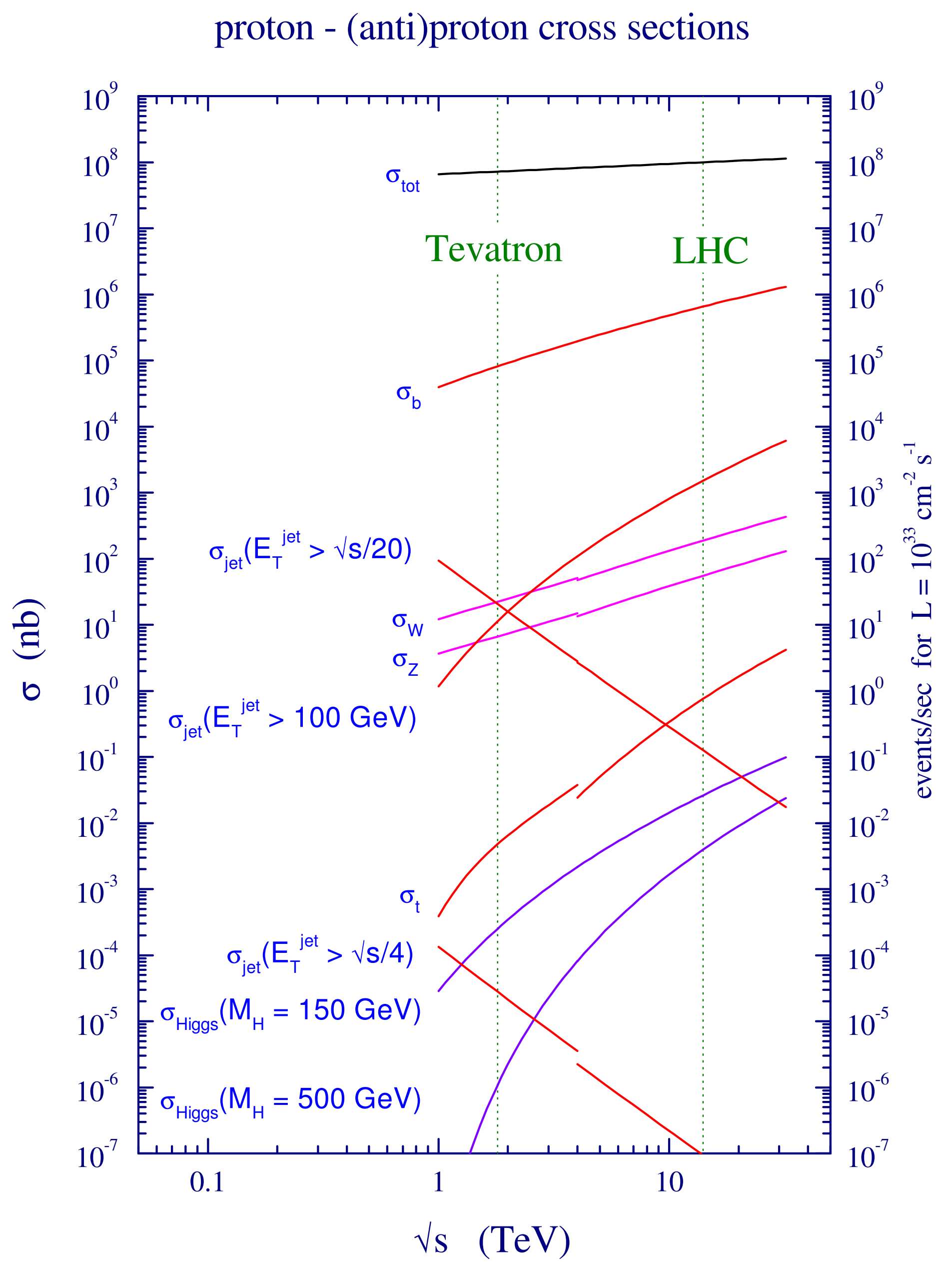


SM Higgs at LHC

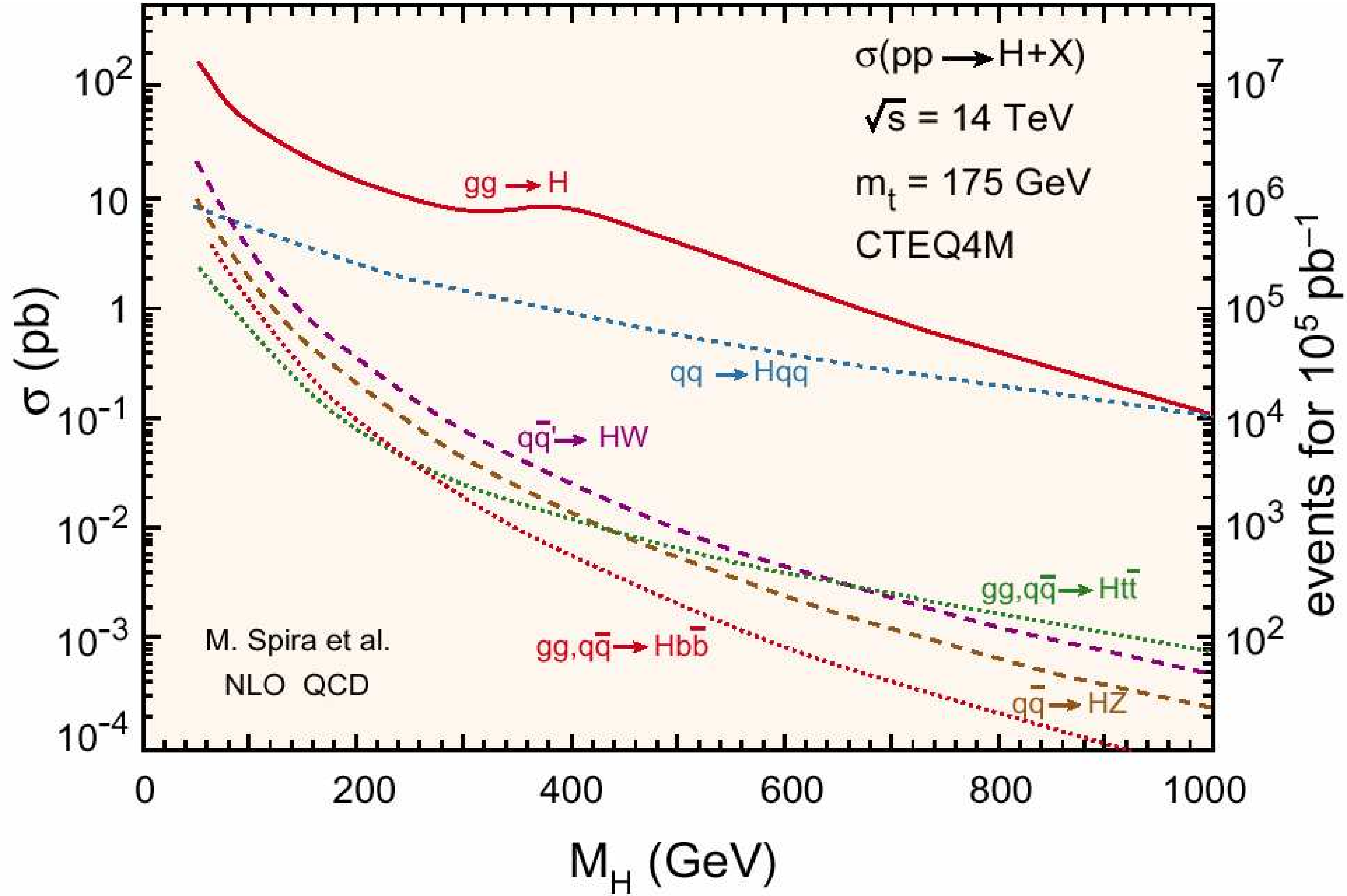
(starts in 1 year!)

The LHC is really a gluon collider!

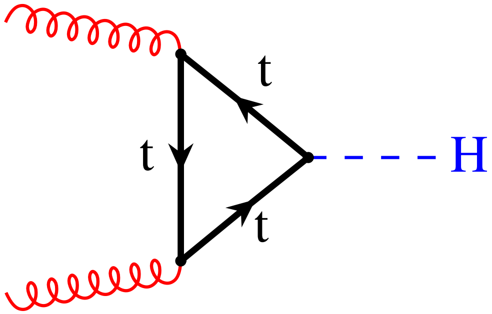
Compared to Tevatron, QCD/EW xsec ratio is much larger – except for H.

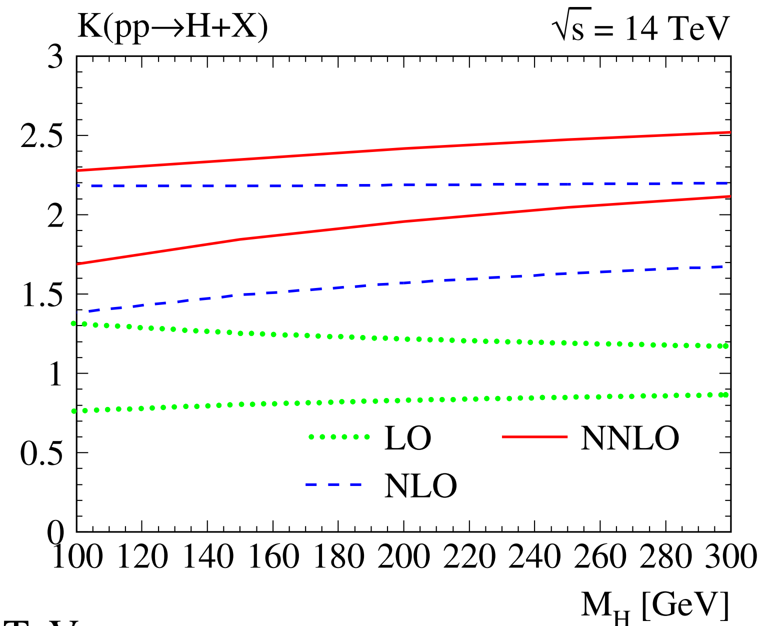


However, while $gg \rightarrow H$ rises QCD-like, the VH channels become relatively quite small.

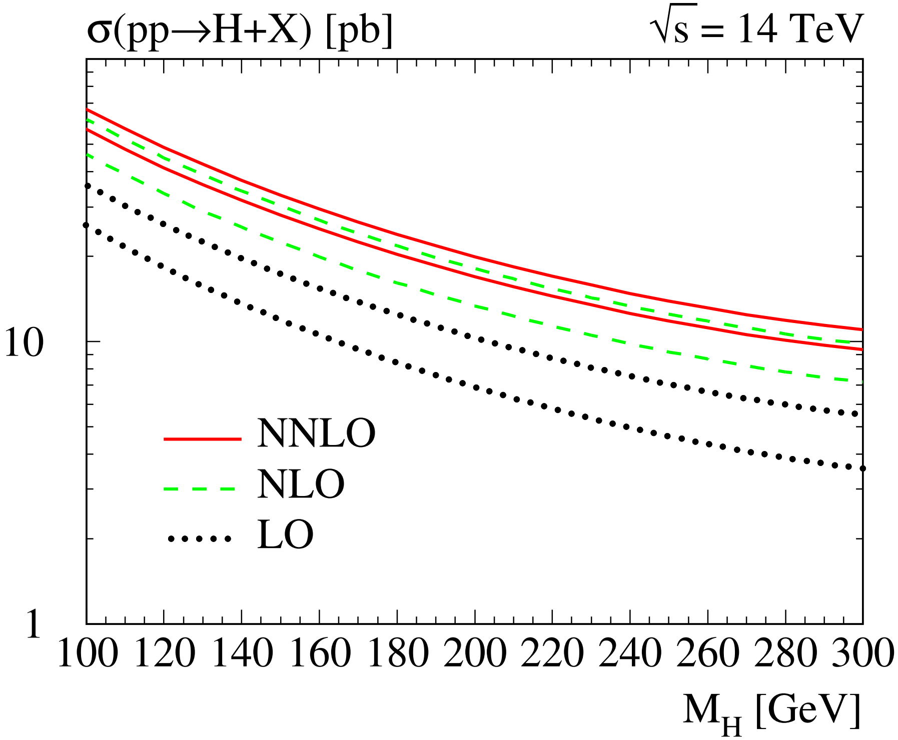


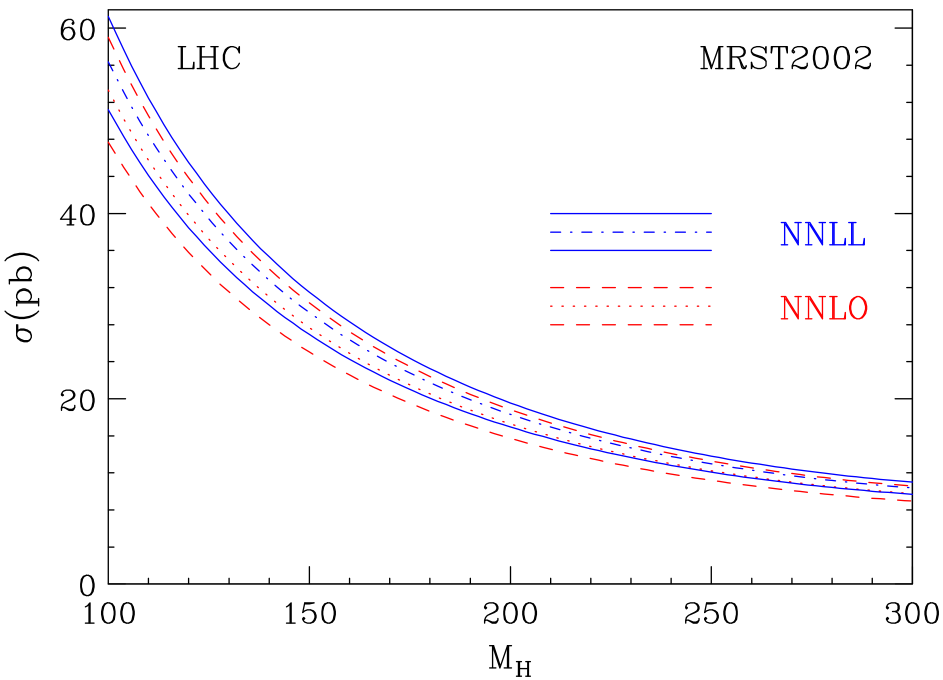
Note: significant QCD corrections to inclusive Higgs production





As cross sections:





$\longrightarrow$ NNLO+NNLL corrections important; $gg \longrightarrow H$ understood well now

What Higgs channels are best as a function of M_H?

Not straightforward: WBF viable @ LHC (unlike Tev2), and need to know:

(a) $\sigma \cdot \mathrm{BR}$

(b) S v. B and uncertainty on (especially) B

(c) detector capabilities

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Not straightforward: WBF viable @ LHC (unlike Tev2), and need to know:

(a) $\sigma \cdot \mathrm{BR}$

(b) S v. B and uncertainty on (especially) B

(c) detector capabilities

Some surprises waiting...

- WBF far better than GF (inclusive) Higgs production
- $t\bar{t}H$ is a tragedy, not a victory
- QCD comes back to bite us
- we know what to do, but aren't prepared to do it

$\longrightarrow$ the old ATLAS TDR is incredibly out of date (CMS TDR out this summer)

In spite of these dire-sounding warnings,

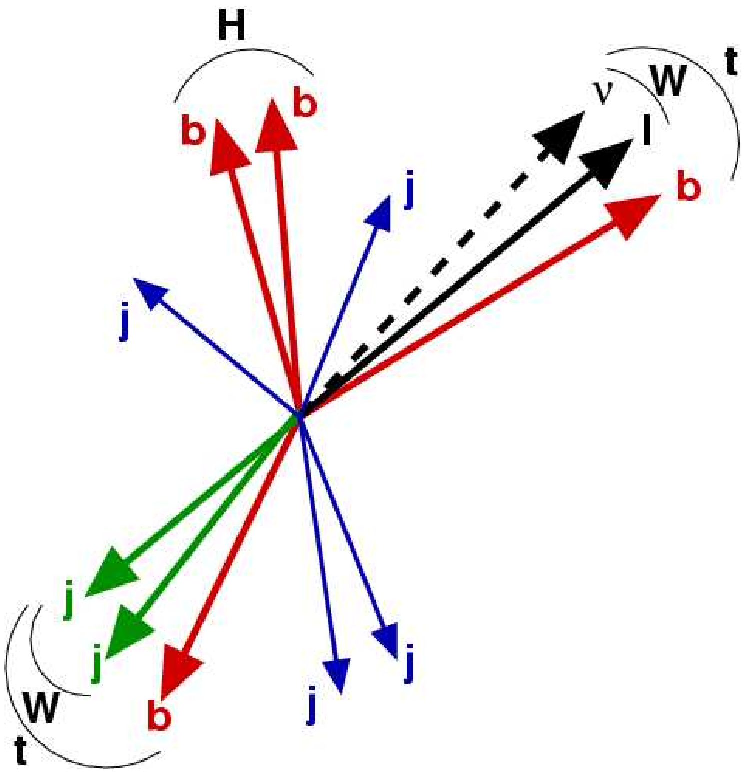
LHC is a far better Higgs factory than we had imagined

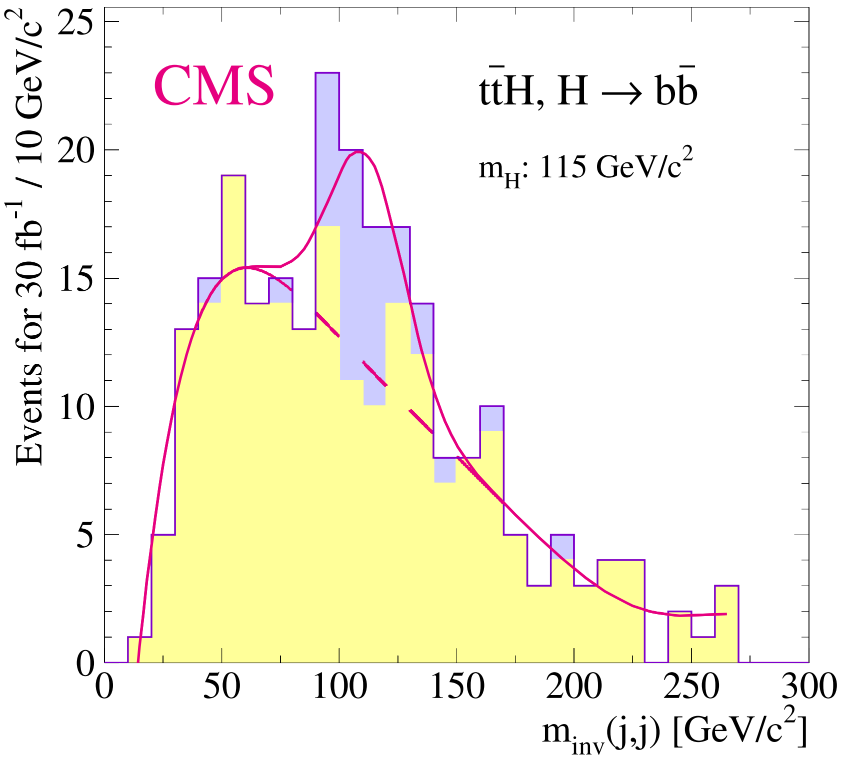
(and just keeps getting better)

The story of $t\bar{t}H$ at LHC

Idea: t-H coupling is "large", and $t\bar{t}H$ signal is highly complex

$\therefore$ unique, should be very little background.





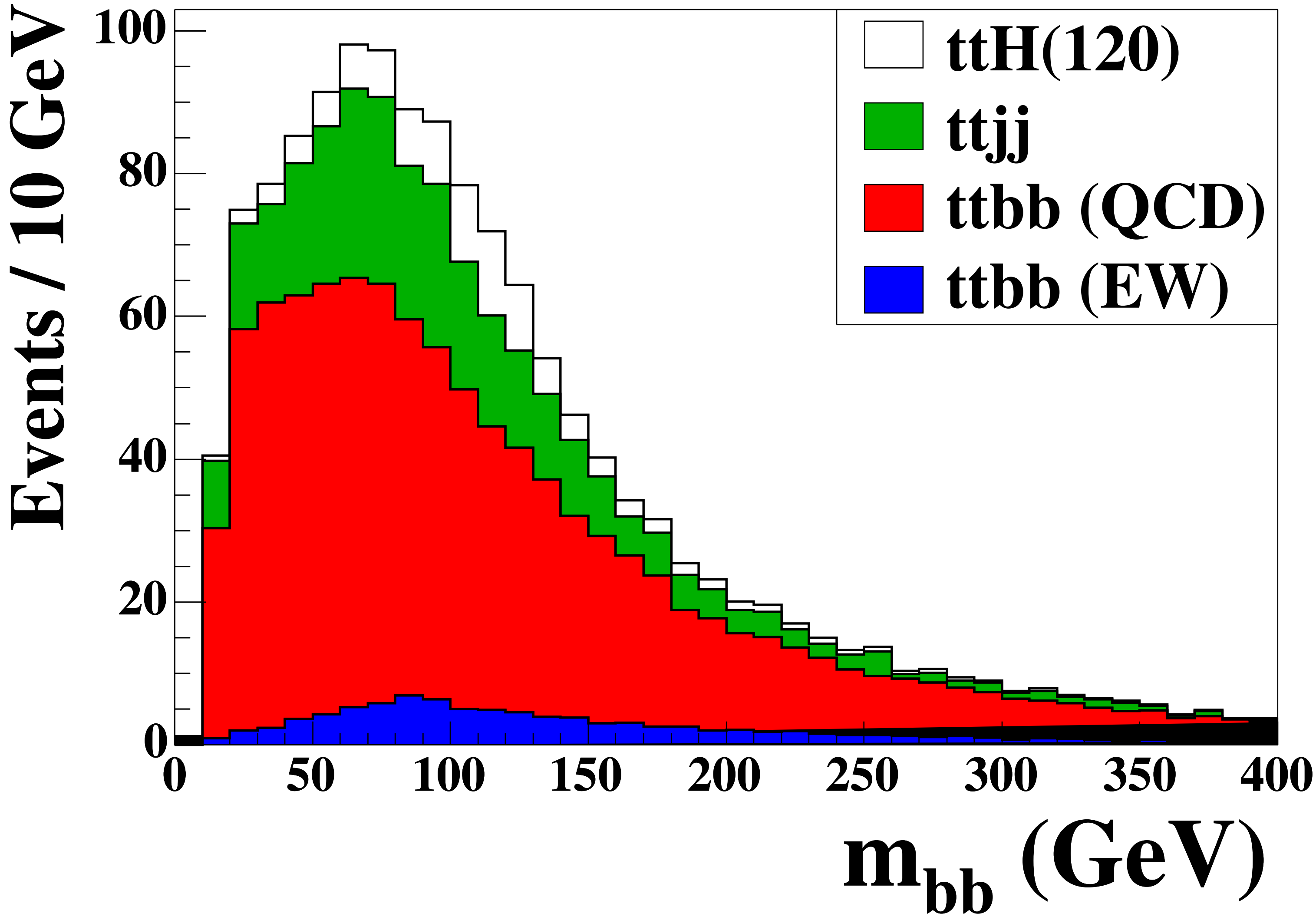
· need ≥ 1 lepton to trigger on events

· original detector studies looked glorious

▶ problem: original studies did not think about QCD carefully!

$\longrightarrow$ $t\bar{t}b\bar{b}$, $t\bar{t}jj$ in the soft/collinear approximation is no good

Current $t\bar{t}H$, $H \to b\bar{b}$ outlook: (30 fb^{-1})



- ▷ S/B now about 1/6 for $M_H = 120$ GeV
- ▶ shape change now very marginal

And in the (lack of) shape lies the sleeping dragon...

There are two types of analysis error in measuring backgrounds:

1. statistical error on sideband measurement
2. systematic error on shape extrapolation to signal region

Significance formula changes: $\frac{S}{\sqrt{B}} \to \frac{S}{\sqrt{B(1+B\triangle^2)}}$

where $\triangle$ is the shape uncertainty (a kind of normalization uncer.)

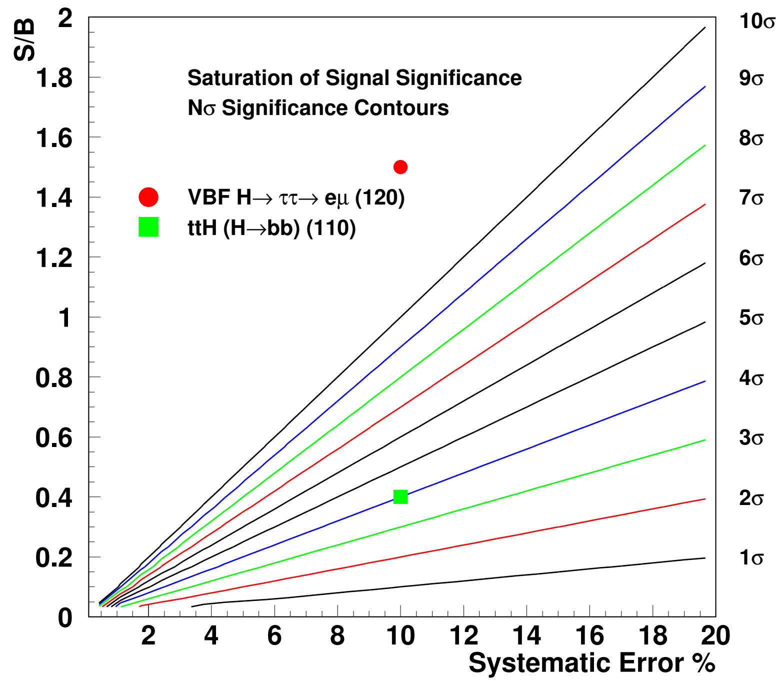
If S/B is fixed as luminosity $\uparrow$, then signif. saturates: $\sigma_\infty = \frac{S/B}{\triangle_{\rm shape}}$

$\triangle = 10\%$ for $t\bar{t}H, H \to b\bar{b}$,

so can never get to 5σ as $L \to \infty$

$\Rightarrow$ limits not just discovery,

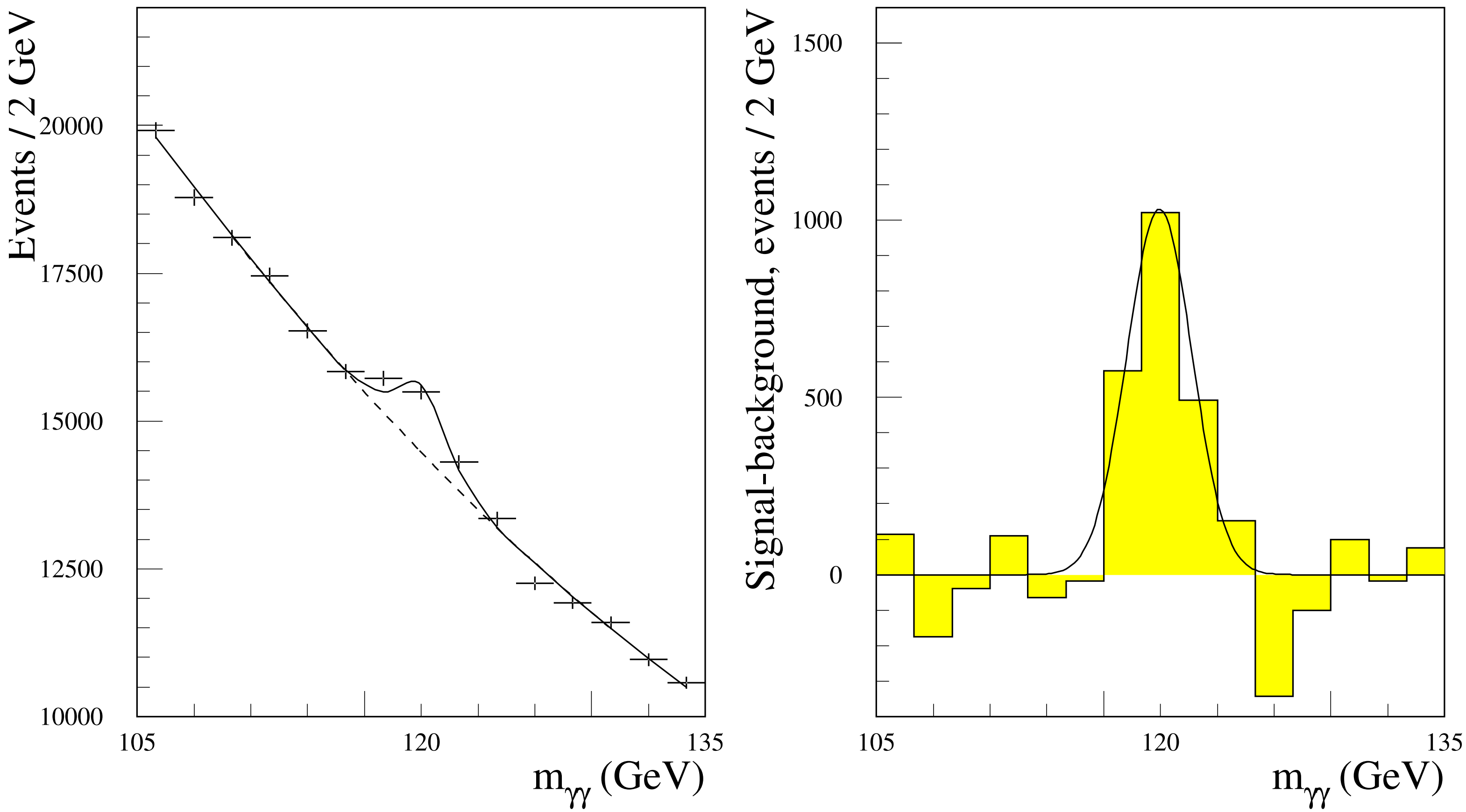
but use as measurment



$gg \to H \to \gamma\gamma$ at the LHC

Idea: rare decay might win because bkg is also EW, not QCD.

(recall BR($H \to \gamma\gamma$) $\sim \mathcal{O}(0.2)\%$ for light $110 \lesssim M_H \lesssim 140$ GeV)



(for 30 fb^{-1})

$\longrightarrow$ might not be discovery, but gets mass to 1%

· requires very good jet (fake photon) rejection – $j\gamma$, jj bkgs non-trivial
detector sim. estimates still range over a factor 2

Still at "low" M_H, what about $H \to \tau^+\tau^-$?

But taus aren't observed directly, they decay immediately:

BR($\tau \to \ell\nu_\ell\nu_\tau$) = 35% $\quad \to$ isolated e or μ ($\epsilon_\ell \sim 90\%$)

BR($\tau \to h_1\nu_\tau$) = 50% $\quad \to$ "1-prong" hadronic ($\epsilon_h \sim 25\%$)

BR($\tau \to h_3\nu_\tau$) = 15% $\quad \to$ "3-prong" hadronic (throw away)

Problem! Lots of missing energy - so how to reconstruct $m_{\tau^+\tau^-}$?

Magic reconstruction technique:

1. assume collinear τ decays: x_+, x_- are unknowns
2. measure $\vec{\not{p}}_T$: knowns are x, y components
3. write momentum conservation matrix and solve for $x_\pm$
4. calculate pair invariant mass: $\boxed{m^2_{\tau\tau} = \frac{m^2_{\ell\ell}}{x_+x_-} + 2m^2_{\tau\tau}}$

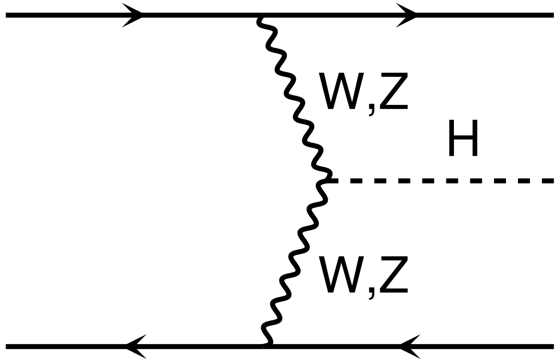
Important note: $\tau^+\tau^-$ must not be back-to-back!

▶ doesn't work then for $gg \to H \to \tau^+\tau^-$

$\Rightarrow$ what about WBF?

So what is this WBF process anyway?

An incoming pair of quarks emit a pair of gauge bosons, which fuse:

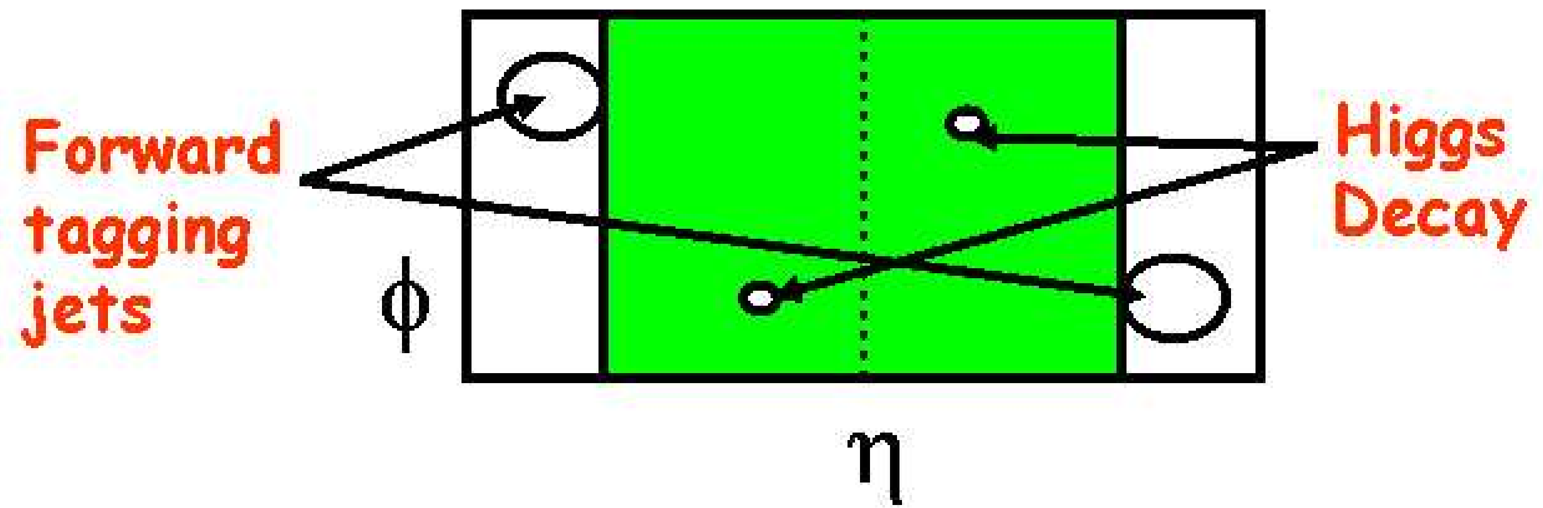


► quarks get scattered far-forward/backward into detector as jets

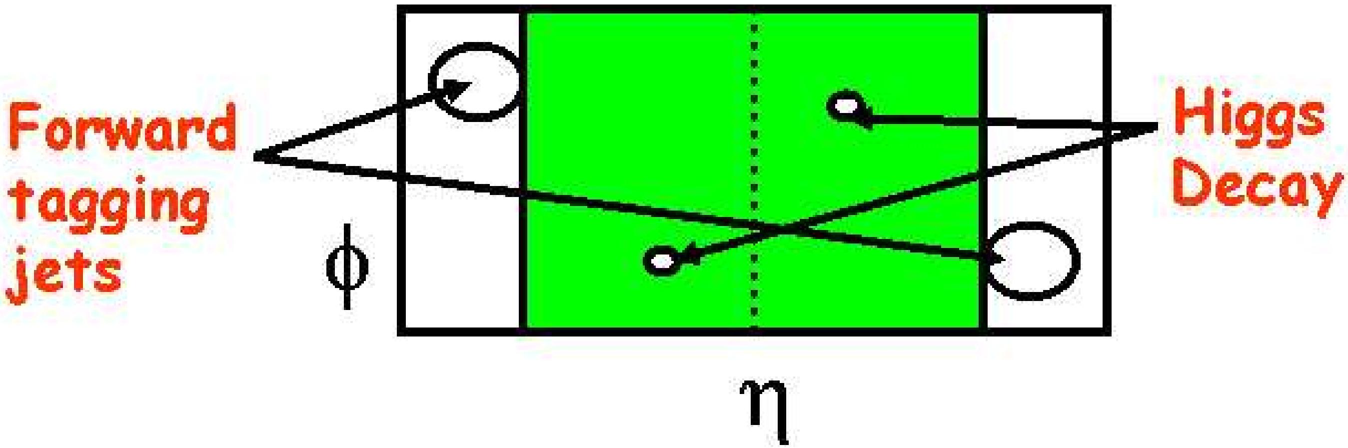
Why? Recall W propagator $\frac{1}{Q^2-M^2}$:

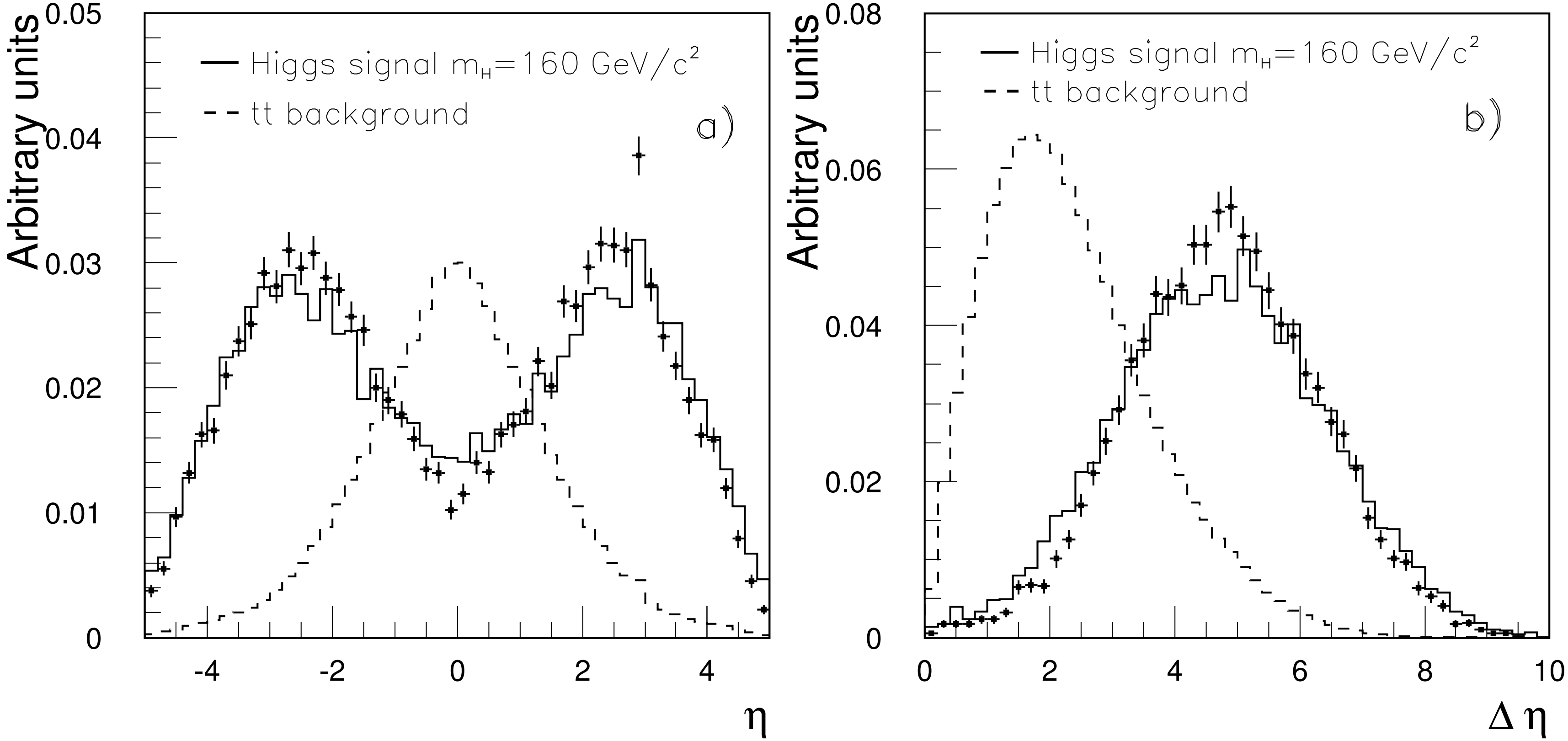
minimal suppression for small Q^2, which is always spacelike

for small Q^2, $Q^2 = (p_f - p_i)^2 \approx E_q^2(1-x)\theta^2$, x small



Sample "tagging jet" distributions against top quark background:





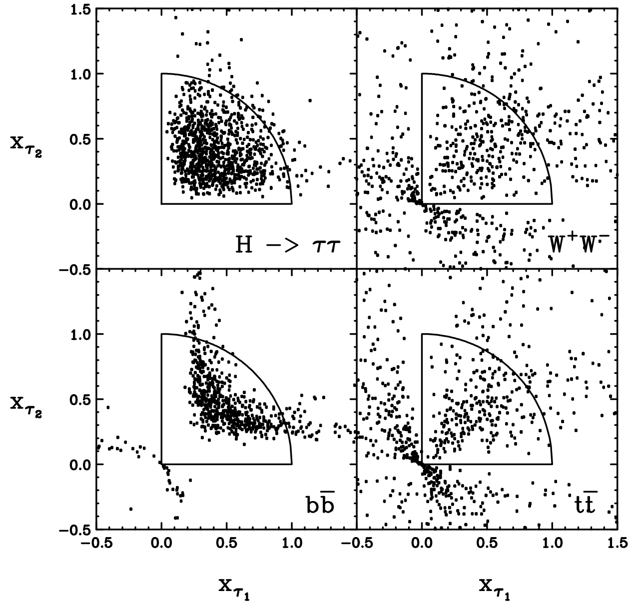
$\longrightarrow$ QCD processes look different

...back to WBF $H \to \tau^+\tau^-$

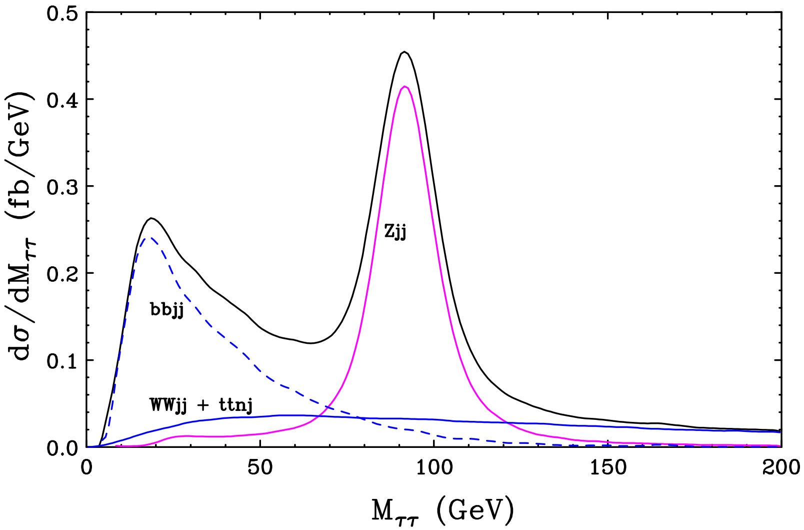
· tau channels to use are $\ell^\pm h$ and $\ell^+\ell^-$ (need a lepton for trigger)

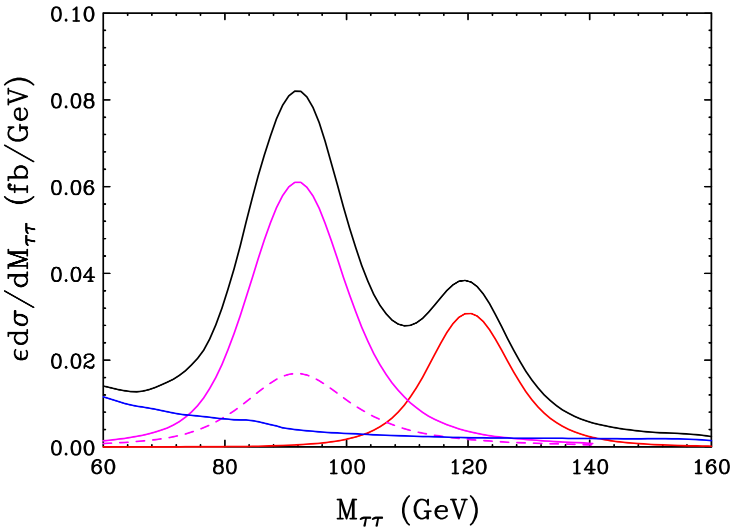
What are the backgrounds? (take $\ell^+\ell'^-$ as example)
$\longrightarrow$ anything which gives two forward jets, $\not{p}_T$ and two leptons

EW	$Zjj, Z \to \tau^+\tau^-$
QCD	$Zjj, Z \to \tau^+\tau^-$
QCD	$t\bar{t}$+jets ($t\bar{t}$,$t\bar{t}j$,$t\bar{t}jj$)
EW	$WWjj$
QCD	$WWjj$
QCD	$b\bar{b}jj$



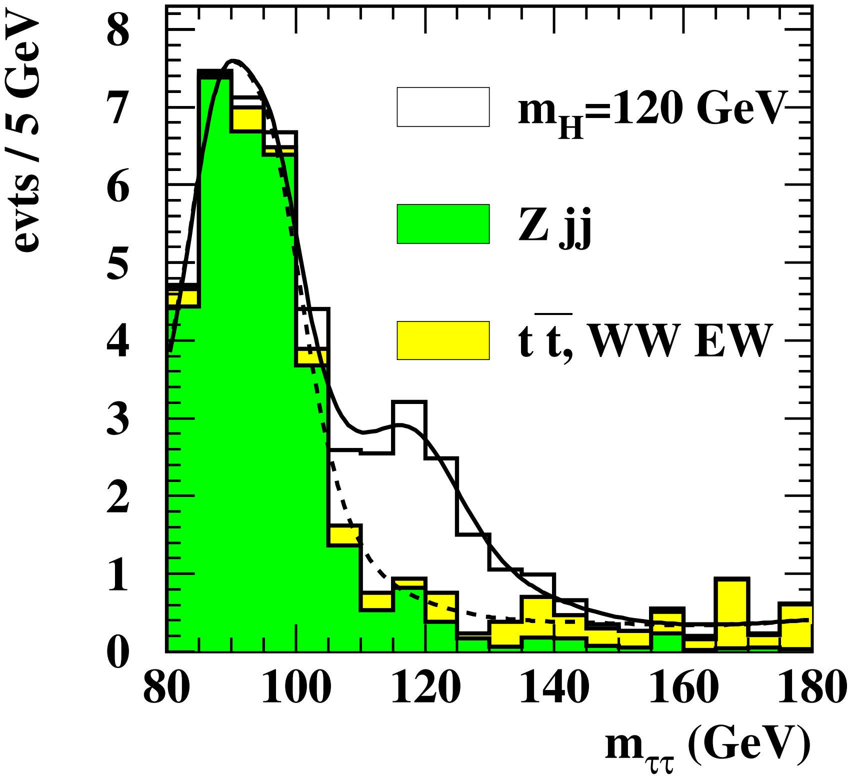
Reducible bkgs don't look like taus $\longrightarrow$
Zjj dominates - mostly QCD $\downarrow$

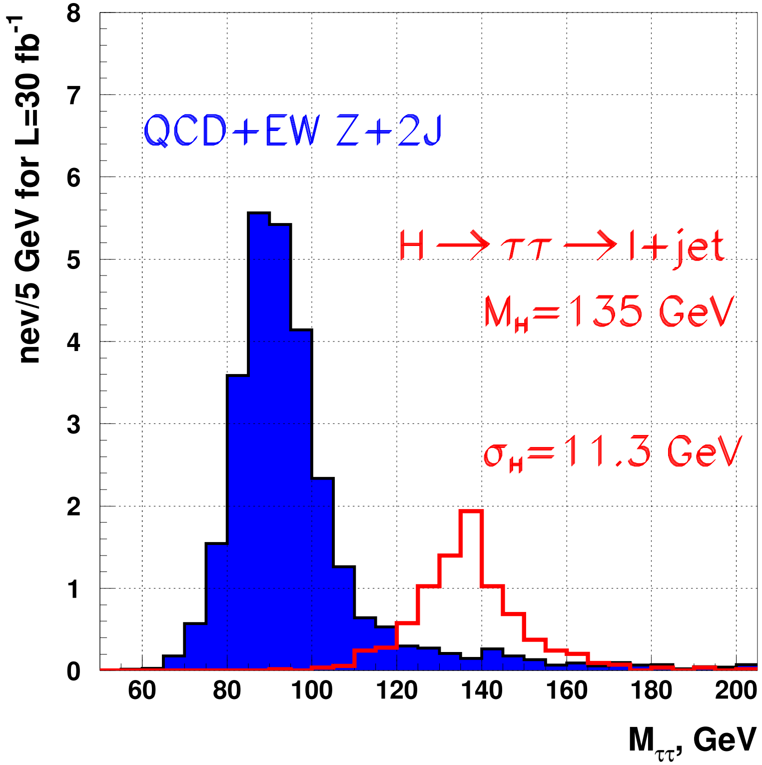




$\longrightarrow$ ATLAS & CMS say: WBF $H \to \tau^+\tau^-$ works *extremely* well,

better than parton-level predictions

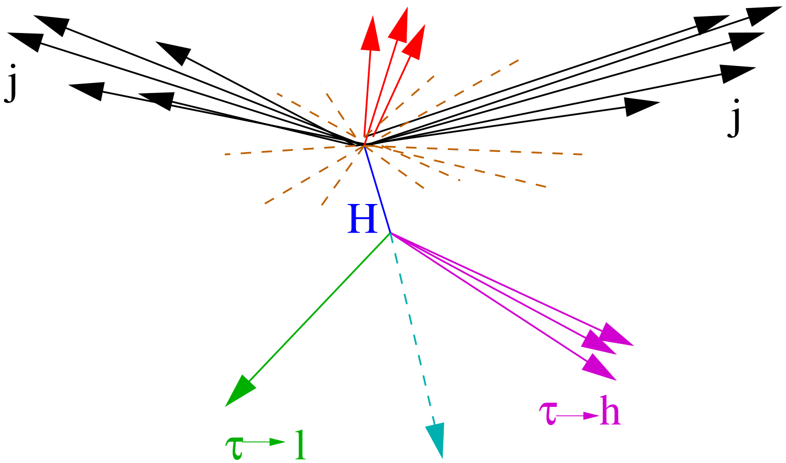


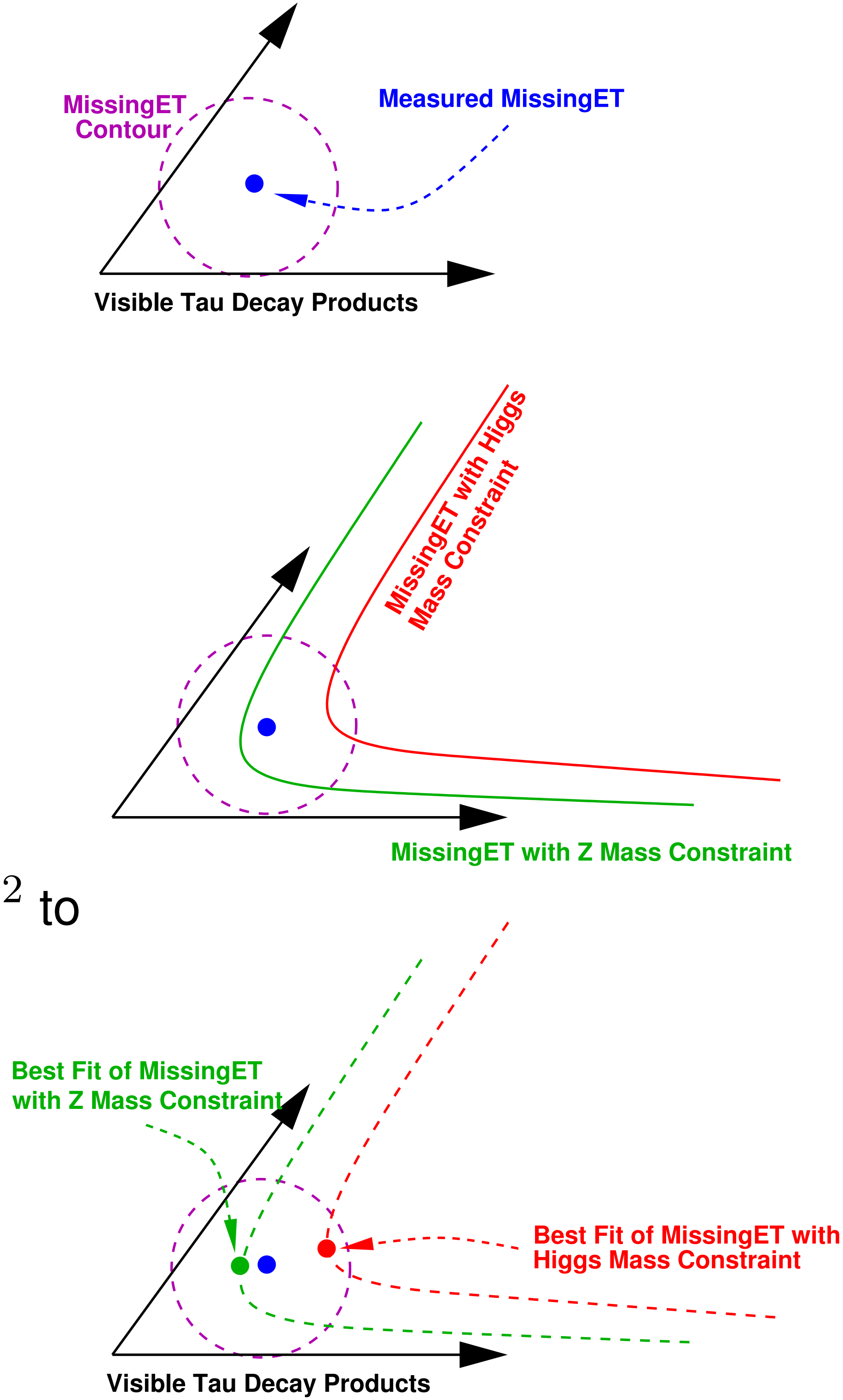


▶ light Higgs easy to observe with 30 fb^{-1} [joint ATLAS/CMS study 2003]

· works for $110 \lesssim M_H \lesssim 150$ GeV (100 fb^{-1})

WBF $H \to \tau^+\tau^-$ in more detail





Major issue is missing transverse momentum resolution (detector):

Perform constrained fit to *both* p-1mm] M_Z and M_H, calculate $\triangle\chi^2$ to determine better consistency with $H \to \tau^+\tau^-$ v. $Z \to \tau^+\tau^-$

$\longrightarrow$ recovers a lot of lost signal

$\longrightarrow$ enhances S/B by factor 4

+ neural net attack on dist'bns, etc.

What if the Higgs is slightly heavier? (say, $M_H \gtrsim 140$ GeV)

$gg \to H \to \gamma\gamma$ loses steam, WBF $H \to \tau^+\tau^-$ gets harder,
$H \to b\bar{b}$ is totally impossible...

- as at Tevatron, look to $H \to W^+W^-, ZZ$ decays

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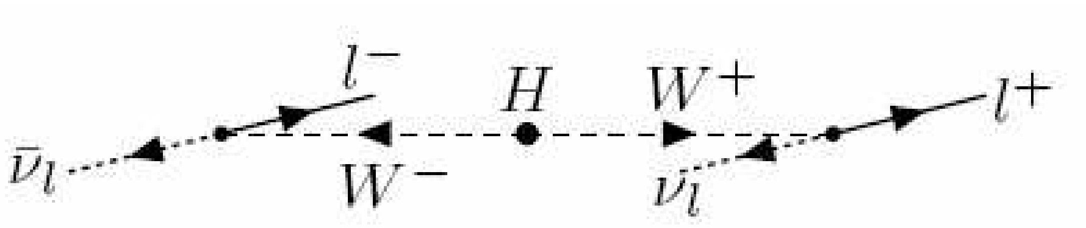
For W^+W^-, recall angular correlation:



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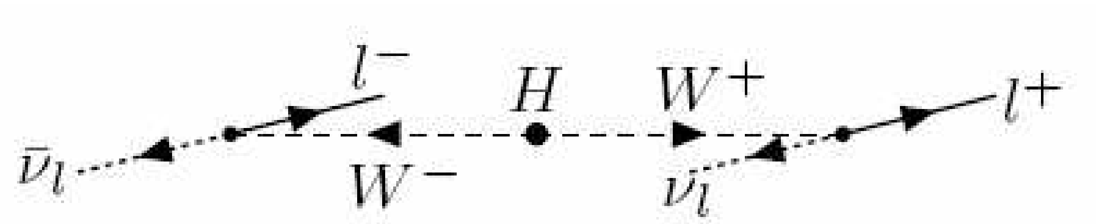


In addition, realize that for $H \to W^+W^-$ at threshold,
the W's are at rest, so $m_{\ell\ell} = m_{\nu\nu}$. Construct transverse mass!

Transverse energies:

$$E_T(e\mu) \;=\; \sqrt{\vec{p}_T^{\,2}(\ell\ell) + m_{\ell\ell}^2} \qquad \& \qquad \not{E}_T \;=\; \sqrt{\vec{\not{p}}_T^{\,2} + m_{\ell\ell}^2}$$

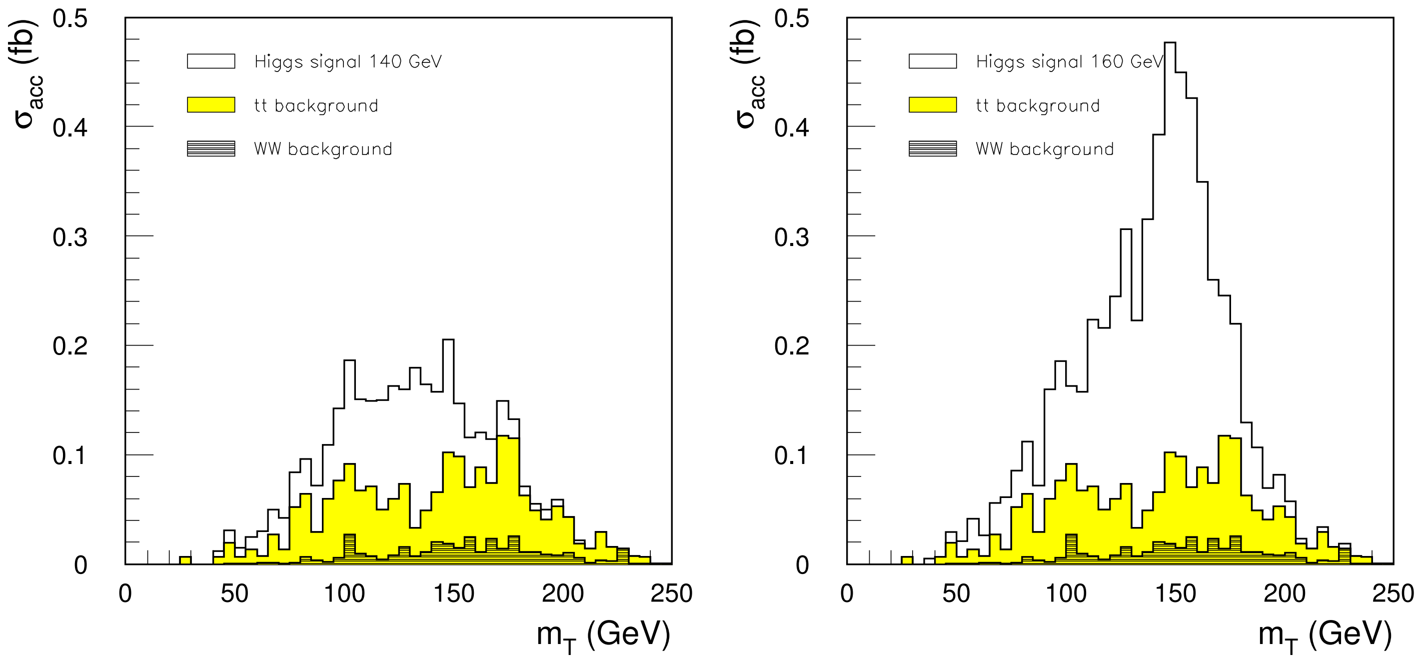
Transverse mass:

$$M_T(W^+W^-) \;=\; \sqrt{(\not{E}_T + E_T(\ell\ell))^2 - (\vec{p}_T(\ell\ell) + \vec{\not{p}}_T)^2}$$

$\longrightarrow$ works well even away from threshold

ATLAS/CMS joint simulation results for WBF $H \to W^+W^-$:

· detector effects smear things out, but Jacobian peak there



Works even for $M_H = 120$ GeV:

channel	signal (fb)		background (fb)					
	VV	gg	$t\bar{t} + Wt$	W^+W^-+jets		$\gamma^*/Z + jets$		total
				EW	QCD	EW	QCD	
$e\mu$	0.52	0.05	0.58	0.27	0.03	0.02	0.05	0.95
$ee/\mu\mu$	0.50	0.04	0.58	0.30	0.03	0.03	0.39	1.33

- for low M_H, serious background uncertainties remain: mostly $t\bar{t}j$ off-shell

▷ needs much more study, and $t\bar{t}j$ @ NLO (on the way, thanks LoopVerein!)

Ok, WBF turns out to be fantastic. How well do we understand it?

Open issues:

1. Minijet veto (QCD radiation effects due to color flow) at primitive stage – but measureable in data (cf. WBF Zjj).

2. Better understanding of $t\bar{t}$+jets: off-shell effects, normalization and shape changes @ NLO.

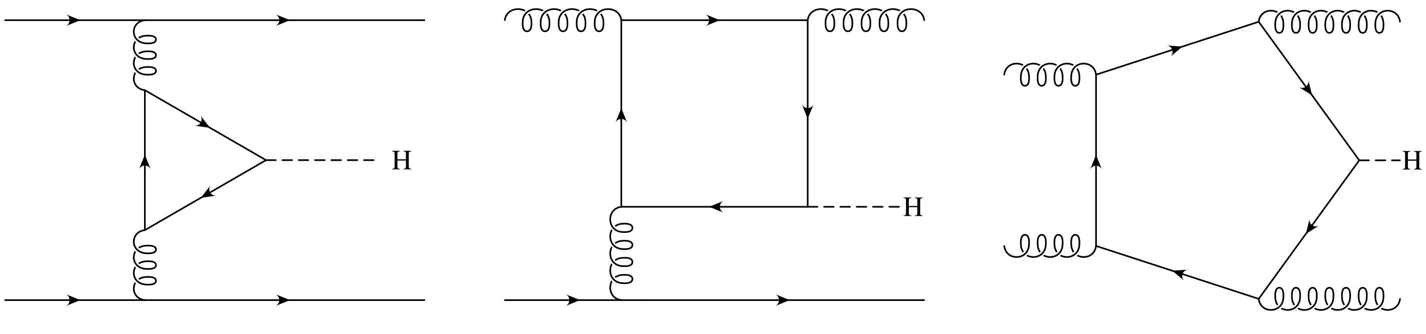
3. Contamination from GF signal + jets: $gg \to Hgg$. Partially understood.

4. Nitty-gritty experimental issues, e.g. tagging forward jets at high lumi w/ underlying event, min. bias, etc.

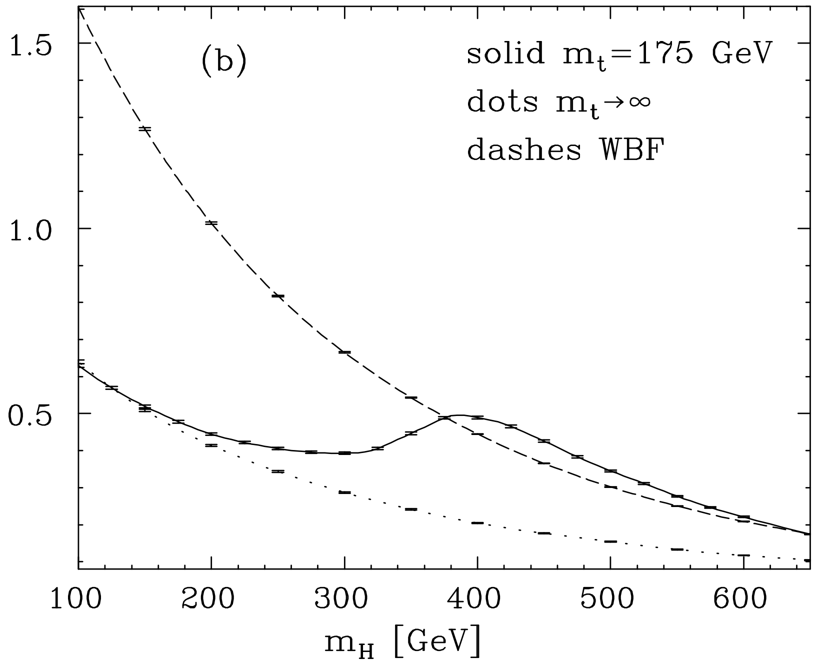
... ?

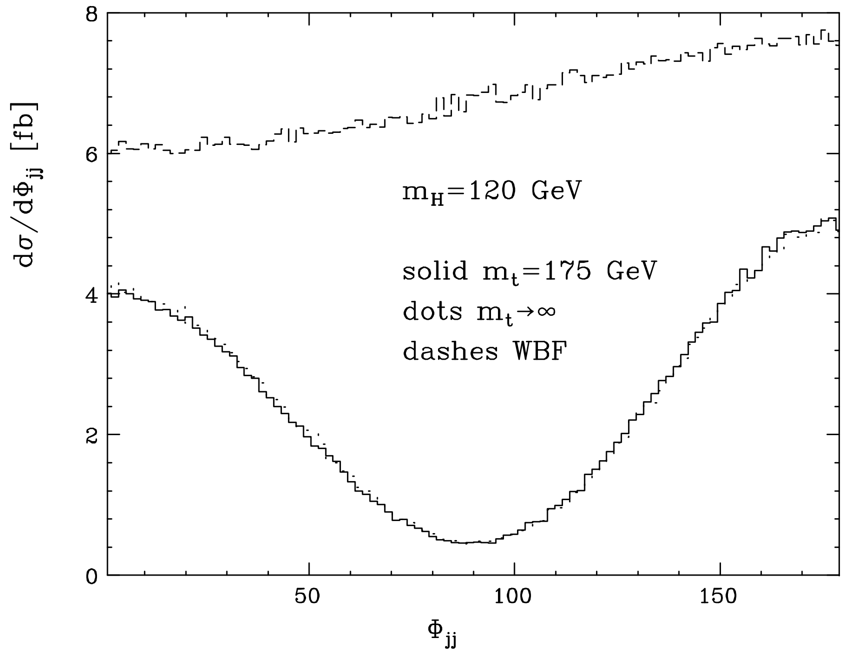
$gg \to Hgg$ “contamination” to WBF Hjj signal

QCD can also give a central Higgs plus forward/backward jets:



(a) (b) (c)

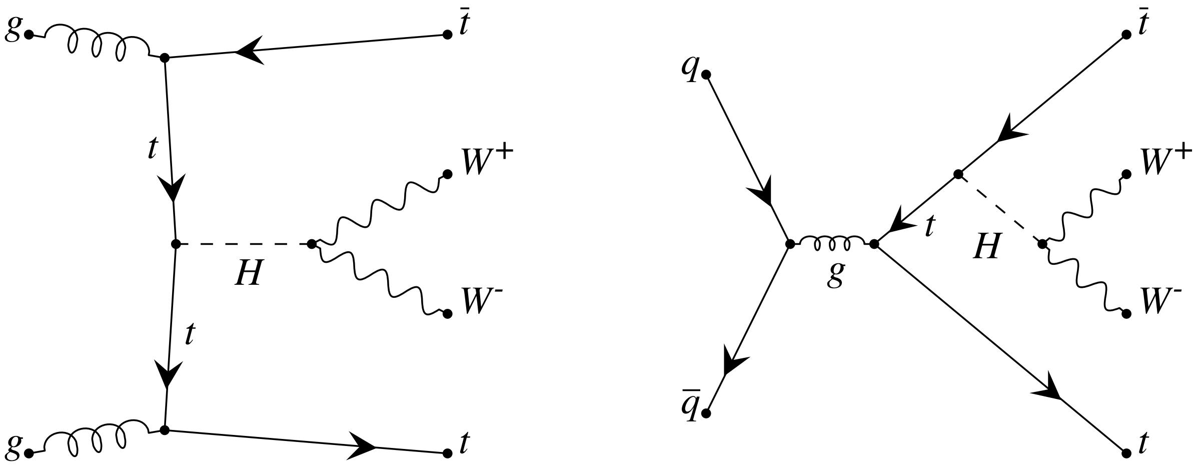




▷ +1/3 rate ↑ w/ WBF cuts @ low M_H! (no MJV) but different ϕ_{jj}

► rate uncertain to more than a factor 2

Big surprise in 2002: $t\bar{t}H, H \to W^+W^-$ is viable!



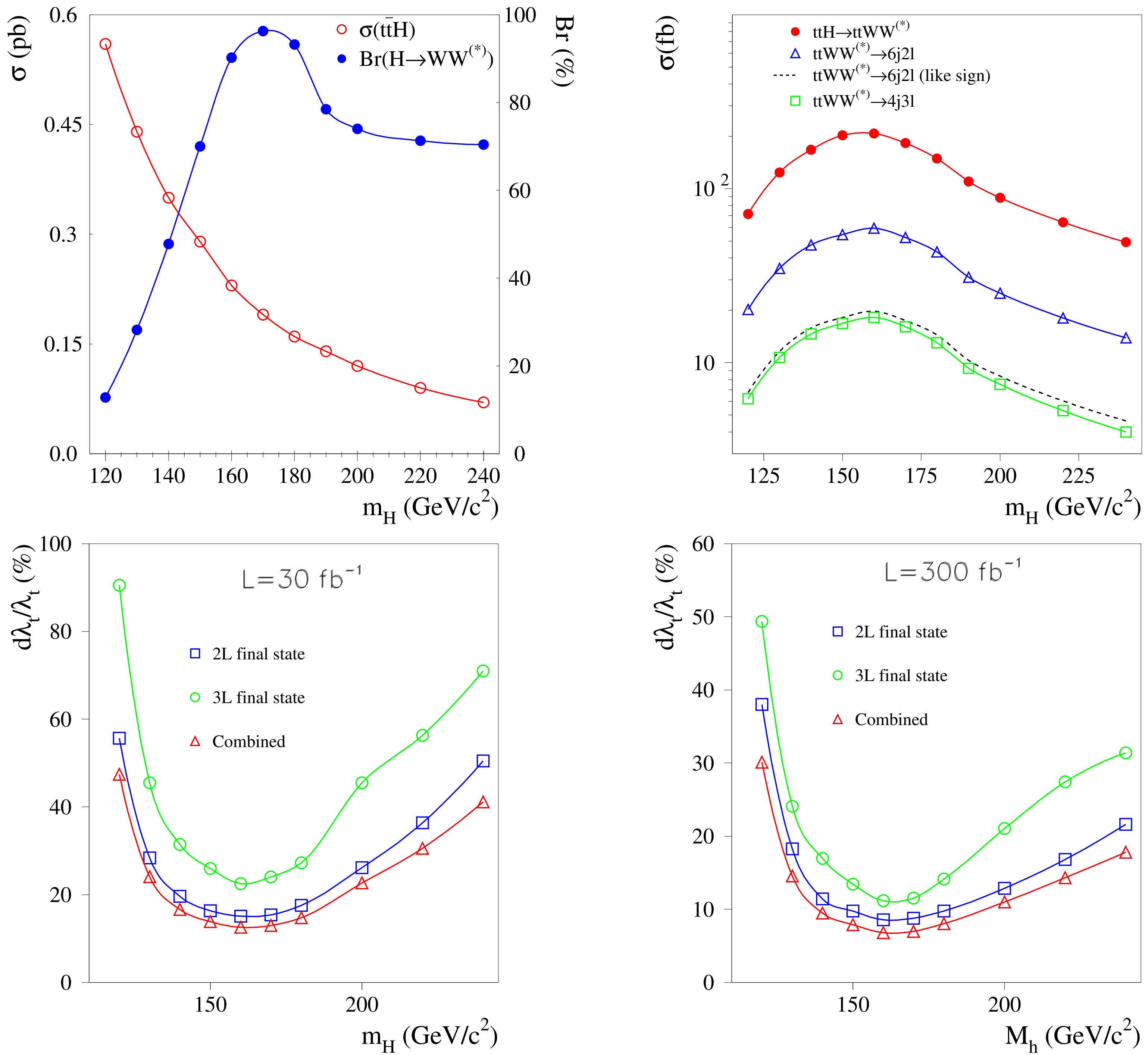
- very complicated final state: $4Wb\bar{b} \longrightarrow$ multipleptons
- best channels: same-sign dilepton, trilepton
- LOTS of nasty, never-before-calculated backgrounds:

  $t\bar{t}Z/\gamma^*(jj), t\bar{t}Wjj, t\bar{t}WW, t\bar{t}t\bar{t}$

  $\longrightarrow$ lots of diagrams, large QCD uncertainties (espec. on $t\bar{t}Vjj$)

► if HWW coupling known, provides only directly Y_t measurement

ATLAS: $t\bar{t}H, H \to W^+W^-$ works over large M_H range: $\sigma \cdot$ BR ∼constant:



Other misc. SM channels ATLAS & CMS are working on:

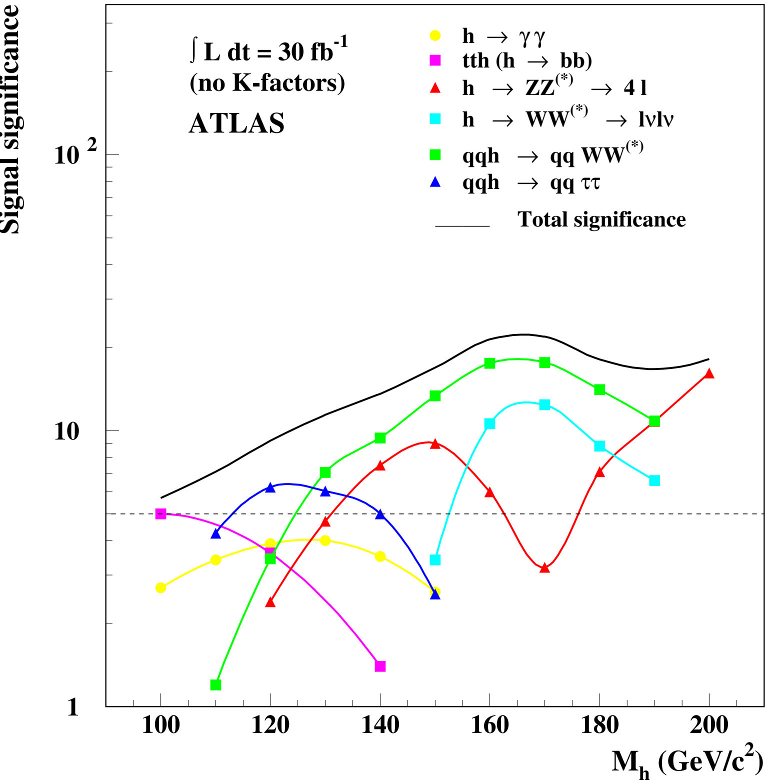
- $gg \to H \to ZZ \to 4\ell$ - the "golden channel" (excellent δm)
- $t\bar{t}H, H \to \gamma\gamma$
- $gg \to H \to W^+W^- \to \ell\nu jj$ (higher mass)
- $gg \to H \to ZZ \to \ell^+\ell^- jj$ (higher mass)
- WBF $H \to W^+W^- \to \ell\nu jj$ (higher mass)
- WBF $H \to ZZ \to \ell^+\ell^- jj,\ \ell^+\ell^- b\bar{b}$
- WBF $H \to \gamma\gamma$
- WBF $H \to \tau^+\tau^- \to h_1 h_1 jj$ (all-hadronic; new trigger)
- ...

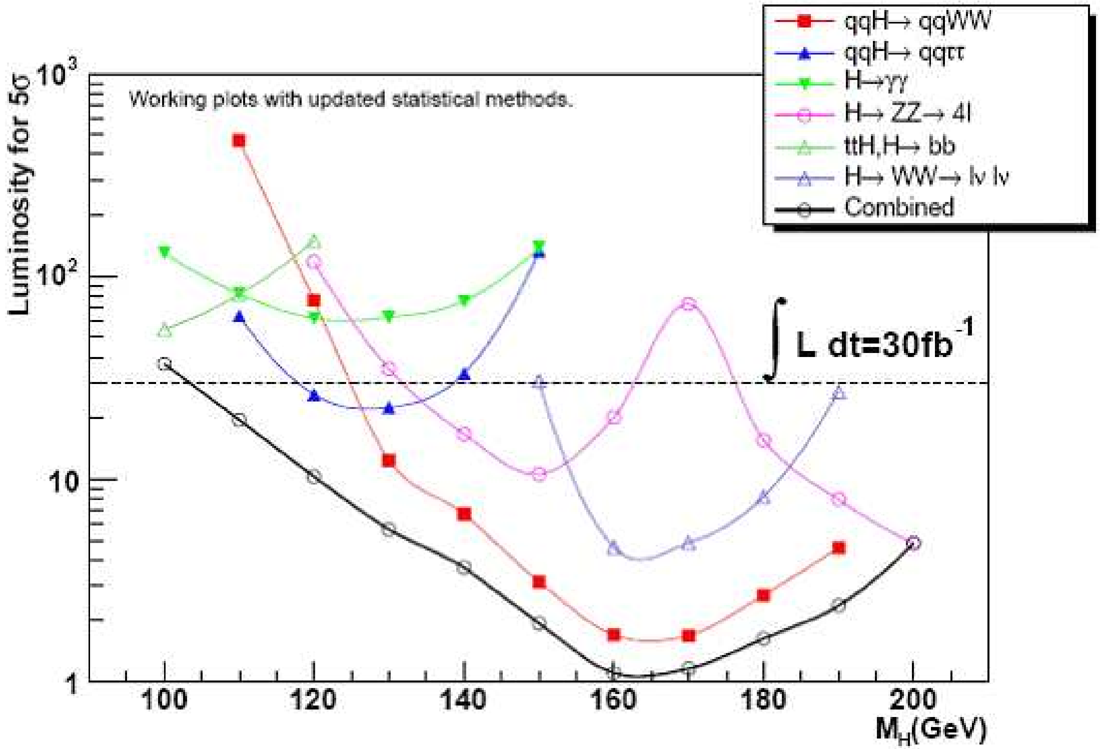
Point: maximize data sample in multiple channels

$\longrightarrow$ allows for more Higgs measurements

...speaking of which...

LHC (ATLAS) SM Higgs discovery summary





- WBF channels most important for discovery (and still not optimal)
  - bad: does not include tagging jet degradation at high lumi
  - good: does not include advances in $H \to \tau^+\tau^-$
  - good: does not include minijet veto at all
  - good: does not include additional W, Z, τ decay channels
- entire mass range covered by multiple channels
- for most range, data contain discovery before detectors understood

SUMMARY PART 1

- The Higgs can't be produced directly, since it couples $\propto$ mass;
  must be produced in associated with or by something massive (W,Z,t,...).
- Higgs partial decay widths to fermions grow like M_H;
  to gauge bosons grow as M_H^3, so these dominate at large M_H.
- LEP didn't find the SM Higgs, Tev2 has a very slim chance.
- The premier production channel at LHC is WBF,
  due to its very good S/B ratio (generally $\gg 1/1$).
- The worst Higgs backgrounds come from QCD.
  Reality check: shape uncertainties can destroy good ideas.
- LHC can discover a SM Higgs of any mass within a few years.

  (We did not discuss heavy Higgs searches, which are a different beast.)
- Clever Higgs-hunting requires careful thought about kinematics.